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The works of the Lord are great, sought out of all them that have pleasure therein.—Ps. cxi, 2.

# THE SIDEREAL MESSENGER.

## OCTOBER, 1891.

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WM. W. PAYNE, EDITOR,

DIRECTOR OF GOODSELL OBSERVATORY, CARLETON COLLEGE.

NORTHFIELD, MINN.

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# THE SIDEREAL MESSENGER,

CONDUCTED BY WM. W. PAYNE.

GOODSELL OBSERVATORY OF CARLETON COLLEGE, NORTHFIELD, MINN.

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## STANDARDIZING PHOTOGRAPHIC FILMS WITHOUT THE USE OF A STANDARD LIGHT.*

PROFESSOR FRANK H. BIGELOW.

The employment of photographic effects as the means of measuring photometrically the intensity of the light emitted by an object, has for a number of years engaged the attention of many experimenters. On the whole, with the accumulation of practical experience, the problem does not look to be so easy of solution as was originally supposed. This is due to the obscurity surrounding the nature of the action of light, when it impinges upon the molecules of the substance to be chemically affected, to our ignorance of the fundamental law that governs the density deposit as a function of the time or of the quality of the light, and to an uncontrollable variation in the effects that are presumably derived from uniform conditions.

In May, 1890, I published Bulletin No. 16 of U. S. Scientific expedition to West Africa, wherein I express a view regarding this subject which I should like to see worked out to a practical conclusion. Since that time no little evidence has been produced which strengthens my original solution, and I propose in this paper to bring the main points together in a general statement of the case.

The first point to be taken up is the general nature of the operation by which light is able to produce a deposit of atoms, or a change in certain sensitive chemical substances. The view which seems to give the greatest satisfaction to students may be summarized briefly as follows: A certain substance is what it is, because the atoms which compose it by unknown causes, are constrained to circulate or oscillate about each other in paths or orbits having definite ampli-

* Read before the American Association for the Advancement of Science at the Washington Meeting Aug. 20, 1891.

tudes and periods; the first grouping of the atoms forming molecules and further groupings constituting the substance. This periodic motion would go on forever, unless energy were conveyed to it from the outside by some process, and if this energy is of the right kind it will disturb the periodic nature of the action. When the energy arrives in the form of the light waves of the ether, we apply a very restricted class of forces out of all that the ether may contain, but to some of the spectrum waves the atomic period becomes sensitive by an accumulation of the impacts of the right type, while to others it is wholly indifferent. Thus it is that certain chemicals respond to given waves but are not influenced by others, and hence arises the method of selective responses in the action of light. If the right waves beat upon the right atomic period, they tend to change the path by expansion or contraction, till at last its original force is overcome and it takes on an orbit of another type; and the molecule being shattered, sets free or deposits an atom, at least so far as the original elements are concerned.

The question arises here as to the nature of the law of the decomposition in its relation to time. We exclude from our discussion that source of variation which arises from a change in the light, or from using at one time certain wave lengths, and at another time other wave lengths. It is clear that the results of different waves acting upon the same atoms, must vary by a complex system of laws, of which we cannot hope to gain a conception until we understand the true laws of natural substance. Let us fix our ideas. Suppose we have 100 atoms forming twenty-five groups or molecules, circulating by the law of the substance. If waves of H length infringe upon them, how will they be deposited or broken up. Some have said that the rule is "the deposit is proportional to the time;" in the first second of time one molecule will be broken up, in the next second one more, and so on, so that at the end of twenty-five seconds all will be broken up. I do not think that this is the correct view, although it is the prevailing one, and has on its side learned men as its advocates.

There is another mode of looking at the law connecting the cause and the effect in this case. If in the first second one molecule is broken up, the energy of the light wave has been able to shatter one twenty-fifth of the total group.

During the next second the light remains the same, but there are only twenty-four molecules to work on, and we shall get not one molecule but $\frac{24}{25}$ of a molecule; or in other words, it requires a little more than one second to pull to pieces the next molecule. This is, we may suppose, due to the fact that in the first second the easiest to break up gives way first; the remaining substance now differs from its original condition by this loss and by the strain introduced into the system by it. Hence the work is becoming more difficult all the time, in this *pari passu* proportion.

Now resorting to mathematics:

Let $F_1$ = the initial energy in the system,

Let $F$ = the energy remaining after the interval of time $t$,

$m$ = the modulus of the decay of the system.

$$\frac{dF}{dt} = -mF\text{, at any instant of time.}$$

$$\frac{dF}{F} = -mdt.$$

$$\log F = -mt + C.$$

$$\text{If } t = 0,\ C = \log F_1.$$

$$\log F = \log F_1 - mt.$$

$$\log \frac{F}{F_1} = -mt.$$

$$\frac{F}{F_1} = e^{-mt}$$

$$F = F_1 e^{-mt}$$

The energy at the end of an interval $t$ equals the original energy multiplied by the Naperian base raised to the negative power $mt$.

This is the law that expresses the change in several well known physical processes, as for example the dissipation of heat by radiation, the decay of an electric current by the resistance of the conductor in which it resides.

In a paper on the "determination of the relation between the exposure-time and the consequent blackening of a photographic film," in No. 6 Publication A. S. P., Mr. Leuschner quotes Captain Abney as having said, at the meeting of the British Association 1889 (p. 493 Report), that his experiments showed "that the intensity was proportional to the time without limitation." This must be an error on Mr. Leuschner's part, for I find that the report says, "the de-

posit of silver made by different intensities of light varies directly as the intensity of the light acting." This is a wholly different statement. The density may be proportional to the intensity of the light, but it is not proportional to the exposure-time, using the same light. Indeed Captain Abney used a formula similar to the one I propose, namely: $T' = T\epsilon^{-\mu x^2}$, $T =$ total transparency,
$T' =$ transparency after time $x$,
$x =$ some power of 2.

My statement of the law is different from Captain Abney's, but this is only a question of analysis, and we both differ from those who assume that the intensity is proportional to the time.

In his paper Mr. Leuschner describes his experiments for testing the question, and concludes, "the law that the blackening of the film is proportional to the exposure time is confirmed within the limits of *two* seconds and eight seconds (within the limits of accidental errors)." The range is too narrow to uphold the law, and the accidental errors are really quite large, so that the case is wholly made out against the commonly accepted view of the subject.

In passing I will call attention to the unsatisfactory condition of the subject as developed by the observers at Mt. Hamilton. Mr. Leuschner shows that great variations exist on the surface of the same photographic film; that is to say, if the plate is subdivided into squares, there is no assurance that any two squares will give the same density when treated as nearly alike as possible during the operations. Some squares were found to be from two to three times as dark as others exposed for the same length of time. This difference of density was due to changes in the sensitiveness of the film in different parts, as well as to changes in the brightness of the standard flame. In a word the experimenter is by no means sure of knowing the conditions under which he is working. The quality of the plate is not uniform and the light is not constant. To show the general hopelessness of standardizing plates on the old plan, I will quote the result of the experience of the Cayenne eclipse party of Dec. 22, 1889. The following table exhibits the treatment to which ten Seed plates, sensitometer No. 26, were subjected, being standardized by squares exposed to a standard light in the usual manner:

*Standard Squares Sept. 24, 1889.*

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| A | Sent to Cayenne and returned to Lick O. | Developed on Dec. 24, at Cayenne. | 5 | A = 0.94 J |
| B | | | 6 | B = 0.92 J |
| C | | Developed on Mar. 17, at Lick Observatory. | 7 | C = 0.55 J |
| D | | | 8 | D = 0.79 J |
| E | Remained at the Lick O. | Developed on Dec. 22, at Lick Observatory. | 3 | E = 1.28 J |
| F | | | 4 | F = 1.01 J |
| G | | Developed on Mar. 17 at Lick Observatory. | 9 | G = 0.38 J |
| H | | | 10 | H = 1.10 J |
| I | Developed on Sept. 24, immediately after standardizing. | | 1 | I = 1.00 J |
| J | | | 2 | |

*Additional Squares March 16, 1890.*

| 6 | 7 | 8 | 9 |
|---|---|---|---|
| | *Second Series.* | *First Series.* | |
| C′ | C′ = 0.61 H′ | C = 0.63 H | C′ = 0.27 J |
| D′ | D′ = 0.67 H′ | D = 0.55 H | D′ = 0.37 J |
| G′ | G′ = 0.36 H′ | G = 1.35 H | G′ = 0.61 J |
| H′ | | | H′ = 0.45 J |

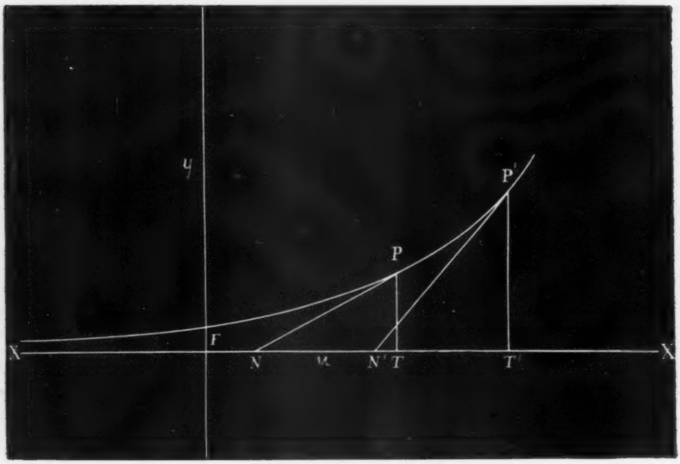
Columns 1 and 6 are the plate marks; column 2 indicates the places at which the plates were retained; column 3 gives the dates of the development of the plates; column 4 the order of development; columns 7, 8 and 9 the equations which represent the relative densities in terms of J, H and H′ as units by which comparisons can be made.

If the plates had behaved in conformity with the uniform conditions which it was intended to produce, if there had been no change in the standard light between the dates Sept. 24, 1889, and March 16, 1890, and if the films had been homogeneous throughout and had remained so, then the coefficients would have been the same in the whole set of equations. We are greatly indebted to Professor Holden for exhibiting so clearly the utter fruitlessness of such photometric work, when an effort is made to secure absolute measures of actinic brightness. Professor W. H. Pickering first applied the method to the eclipse of 1886, and gave a series of measures of the brightness of the corona in its various parts, and several other related measures of sky light, moon light, and such quantities. These measures would be of great value if they were really absolute, inasmuch as the varying brightness of the corona could be compared from time to time. As it is the range in the measures obtained is enormous, and no confidence can be placed in the accuracy of the work. We are now in possession of the argument sufficiently to pro-

ceed to the solution we propose for the problem. Resuming the formula, we have at the end of the intervals $t'$ and $t''$ respectively.

$$\log F' = \log F_1 - mt',$$
$$\log F'' = \log F_1 - mt'',$$
$$m = \frac{\log F' - \log F''}{t'' - t'}.$$

The equation $F = F_1 e^{-mt}$ is that of a logarithmic curve. If we put $t = \frac{x}{n}$ and $F = y$, we have $y = F e^{-\frac{x}{n}}$, that is $m = \frac{1}{n}$. Now $n$ is the constant subtangent which is characteristic of the curve, its reciprocal being the modulus of the system.




$F$ = the intercept of the curve on $y$.
$n$ = the constant subtangent, $NT$, $N'T'$.
$\frac{x}{n}$ = the time of exposures.
$y$ = the corresponding density products.
After two exposures

$$m = \frac{\log F' - \log F''}{t'' - t} = \frac{1}{n}$$

If we have a plate with a certain density coefficient $\frac{1}{n}$, it is seen that two exposures from the same light will produce

two different density products relative in this manner. Now it is seen by an inspection of the formula for $m$, that we have eliminated the original density $F_1$, that there is no assumption regarding the light used, and that the elements of uncertainty are reduced to a minimum. If different lights were to be used on the same film, they would, at the end of the intervals $t'$ and $t''$, pick out two pairs of points $P$, $P'$, related to each other in such a way as to produce the same modulus to the curve.

We therefore are reduced to two comparatively simple conditions, first, the accurate estimate of the interval of time $t'' - t'$, and second, the determination of the quantities F′ and F″. The first we can pass over as obviously without difficulty. The values of $F'$ and $F''$ are relative densities, and we may suppose them closely relative to the average number of molecules thrown down.

If we take 100 as representing the color or the plate before exposure, and 0 the density color at its maximum, or when the light action begins to reverse the density product, we can suppose that a visual scale from 100 to 0 will give all the intermediate density shades perceptible to the eye.

If an exposure of 10 seconds gives a density which matches 50 on the scale, and exposure of 15 seconds one that matches 40, we get:

$$m = \frac{1.69897 - 1.60206}{15 - 10} = \frac{0.09691}{5} = 0.01338$$

$$n = \frac{1}{m} = 9.98662 = .96966,$$

which will characterize this film. The serious task is to secure the standard scale. It will need to be a work of art and will require much skill to produce it, for it is well known that nothing is more vexatious than to produce evenly graduated shadings of black and white. The behavior of all the parts concerned is often inexplicable.

After duly considering the case, I am inclined to think that the simplest way to get at a scale will be to make a large number of bits of buck with varying shade, and then by trial place them along side of each other in the right order. This problem is so promising that we may hope some photographer will attempt to produce a prototype scale that can be used in this connection. For it would seem, at least theoretically, that this will afford a means of escape from the very unsatisfactory condition of affairs which now exists either regarding the standardizing of plates, or as regards the application of photography to any kind of photometric use.

### SIR G. B. AIRY.

THE ninetieth birthday of Sir G. B. Airy (1891, July 27) is an event of such general interest that we feel sure a brief reference to its celebration by his family and friends will not be deemed an impertinence. Saturday, July 25, was fixed for the reception in honor of the event, and Sir George received in person the congratulations and good wishes of a large and distinguished company.

Astronomy was represented by many familiar faces, including those of the Astronomer Royal, the President of the R. A. S., and the Hydrographer to the Navy. It was delightful also to see Mr. Perigal, who walked up the hill with almost a jaunty step. Trinity College, Cambridge, of which Sir George is both the oldest ex-Fellow and the oldest Honorary Fellow, was represented by its master, Dr. Butler. There were many other guests whose presence was significant, as, for instance, Mr. Biddell, who was forty years ago charged by Messrs. Ransomes and May with the construction of the present Transit Circle. He described to a small knot of most interested guests the dismay of the workmen and their employers at the demands of Sir G. B. Airy, especially those relating to the pivots. These were to be of chilled iron, 6 inches in diameter, and perfect cylinders to within $\frac{1}{30000}$ inch! No error of this magnitude was to be discernible with a delicate spirit-level; and after trying all the most delicate methods of turning then known, the requisite accuracy was obtained by sheer labour—rubbing down bit by bit all the places which this same spirit-level indicated as too high. Each of the pivots cost six weeks of such labour!

Monday, July 27, the actual anniversary, was marked by the performance of a singularly appropriate ceremony. Sir George turned on, for the first time, the gas which is to illuminate the Parish Church clock of Greenwich, and which will now be automatically and regularly turned on by the clock during the evening hours. The very hour (9 o'clock) at which he was thus once more concerned with Greenwich time was curiously in keeping with the occasion, and the excellent speech with which he concluded the ceremony bore evidence to his marvellous vigor. We sincerely hope to be present at an even more important celebration ten years hence.—*Observatory, August, 1891.*

## SOME TELESCOPES IN THE UNITED STATES.

WM. H. KNIGHT.

FOR THE MESSENGER.

The following partial list of telescopes in the United States is epitomised from materials I have been collecting during the past two years with a view to publishing a catalogue of the observatories of the world, together with their equipment and personel. In the present list I have included only those instruments of which the aperture is 4 inches or upwards.

It will be seen that the twelve largest refracting telescopes are those of the Lick Observatory with an aperture of 36 inches, Yale University 28, U. S. Naval 26, Leander McCormick 26, Princeton 23, Denver 20, Smithsonian 20, Dearborn 18.5, Carleton College 16.2, Warner 16, Washburn, 15.5 and Harvard 15.

The largest reflecting telescopes are those of Harvard College, 28 inches, and Rev. Dr. John Peate 22. Dr. Peate, who is an amateur maker, is now finishing up a 30½ inch silver-on-glass mirror, which will be presented to the Allegheny College at Meadville: When mounted it will be the largest reflecting telescope in this country. There are numerous reflectors made by Brashear from 9 to 12 inches in diameter.

The Clarks are now grinding an object glass of 40 inches for a telescope to be mounted in an Observatory yet to be built upon Mount Wilson in Southern California.

Though the Lick Observatory possesses the largest telescope at present, Harvard College has the best equipped Observatory for general astronomical work in America, and one of the best in the world.

In foreign countries the largest refractors are those at Pulkowa, near St. Petersburg, 30 inches, Nice 29.75, Vienna 26.75, Gateshead near London 25, and Paris 23.6.

The largest reflectors are those of Lord Rosse in Ireland 72 inches, Melbourne 48, Paris 47, Mr. Common's in England 37.5, another of Lord Rosse 36, Toulouse 32.4, Marseilles 31.5, Greenwich 28, and Cambridge 24.

| *Location.* | *Owner.* | *Description.* |
|---|---|---|
| Akron, O. | Buchtel College Observatory | 4.5-in. |
| Albany, N. Y. | Dudley Observatory | 13-in. Refractor |
| | | 6-in. Mer. Circle. |
| Alfred Center, N. Y. | Alfred Observatory | 9-in. Refractor |
| Allegheny, Pa. | Allegheny Observatory | 13-in. Refractor |
| | | 10-in. Reflector |
| Amherst, Mass. | Amherst College Observatory. | 7.25-in. Refractor |
| | | 6.37-in. Tran. Cir. |
| Annapolis, Md. | Annapolis Observatory | 7.75-in. Refractor |
| | | 4-in. Mer. Circle |
| Ann Arbor, Mich. | Detroit Obs. of the Univ. of Mich. | 12.4-in. Refractor |
| | | 6-in. Mer. Circle |
| Appleton, Wis. | Underwood Obs. of Lawrence University. | 10-in. Refractor |
| | | 4-in. Transit Circle |
| Augusta, Me. | Melville Smith | 8.5-in. Reflector |
| Baltimore, Md. | Johns Hopkins University | 9.5-in. Refractor |
| Baltimore, Md. | Geo. Gildersleve | 6.1-in. Refractor |
| Baltimore, Md. | Normal School | 6-in. |
| Baltimore, Md. | John R. Hooper, M. D. | 5-in. Refractor |
| | | 4.1-in. Refractor |
| Baltimore, Md. | Denmore Observatory | 4-in. Refractor |
| Baltimore, Md. | Justice Stahn | 6-in. Refractor |
| Beloit, Wis. | Smith Obs. of Beloit College | 9.5-in. Refractor |
| Berkeley, Cal. | Students Obs. of the Univ. of Cal. | 6-in. Refractor |
| Boston. Mass. | Boston University | 7-in. Refractor |
| Brighton, Mass. | Edwin F. Sawyer | 4.37-in. Refractor |
| Brooklyn, N. Y. | Henry M. Parkhurst | 9-in. Refractor |
| Brunswick, Me. | Bowdoin College Observatory | 6-in. Refractor |
| Cambridge, Mass. | Harvard College Observatory | 28-in. Reflector |
| | | 24-in. Bruce Photo. |
| | | 15-in. Refractor |
| | | 15-in. Reflector |
| | | 13-in. Rev. Photo. |
| | | 12-in. Horizontal |
| | | 11-in. Photo. |
| | | 8-in. Transit Circle |
| | | 8-in. Photo. Doub. |
| | | 4.25-in.Com. Seeker |
| Camden, N. J. | Camden Observatory | 5.5-in. Refractor |
| Camden, N. J. | A. B. Depuy | 9.5-in. Reflector |
| Charlottsville, Va. | Leander McCormick Observatory of the University of Virginia. | 26-in. Refractor |
| | | 4-in. Refractor |
| Chicago, Ill. | Kenwood Physical Observatory | 12.2-in. Refractor |
| Chicago, Ill. | Samuel Harris | 4.25-in. Refractor |
| Cincinnati, O. | Cincinnati Observatory of the University of Cincinnati | 11-in. Refractor |
| | | 5.12-in. Mer. Circle |
| | | 4-in. Refractor |
| Clinton, N. Y. | Litchfield Observatory of Hamilton College | 13.5-in. Refractor |
| | | 5-in. Refractor |
| | | 4-in. Refractor |
| Columbia, Mo. | Observatory of the Univ. of Mo. | 7.5-in. Refractor |
| Columbus, O. | Ohio State University | 4-in. Refractor |
| Crete, Neb. | Boswell Observatory | 8-in. Refractor |
| Dansville, N. Y. | Patterson Observatory | 5-in. Refractor |
| Denver, Col. | Chamberlin Observatory of the University of Denver. | 20-in. Refractor |
| | | 6-in. Refractor |
| Evanston, Ill. | Dearborn Obs. of N. W. University | 18.5-in. Refractor |
| Fall River, Mass. | Durfee High School | 8-in. Refractor |

| *Maker and Date.* | *Astronomers.* | *Special Work.* |
|---|---|---|
| Pike | H. V. Egbert, Director | Educational |
| Fitz | Lewis Boss, Director | Comets |
| | | |
| Fitz | F. S. Place, Director | |
| Fitz, 1861 | James E. Keeler, Director; Frank | Solar Physics, Spec- |
| Brashear | W. Very, Observer | troscopy |
| Clark | David P. Todd, Director | Jupiter's Satellites, |
| Pistor & Martins | | Sun Spots |
| Clark | | |
| Repsold | | |
| Fitz | Mark W. Harrington, Director; | Star Positions |
| Pistor & Martins | W. J. Hussey, Observer | |
| Clark, 1891 | L. W. Underwood, Director | Educational |
| Clark | | |
| Brashear | | |
| 1887 | Chas. A. Borst, Director | |
| Hastings, 1884 | Geo. Giddersleve, Observer | Solar Observations |
| | | |
| Clark, 1866 | John R. Hooper, Director | Sun Spot Records, |
| Hastings, 1879 | | Comets |
| Cooke | W. H. Numsen, Observer | |
| 1889 | M. B. Stahn, Observer | |
| Clark, 1882 | Charles A. Bacon, Director | Solar Prominences |
| Byrne | Frank Soulé, Director | Planetary Studies |
| Clacey | Judson B. Coit, Director | Educational |
| Clacey, 1882 | Edwin F. Sawyer, Director | Variable Stars |
| Fitz, 1877 | Henry M. Parkhurst, Director | Asteroid Photome- |
| | | try. |
| Wray, 1886 | | Educational |
| Draper | Edward C. Pickering, Director; | Photometry, Pho- |
| 1890 | Arthur Searle, S. C. Chandler, | tography, and |
| Merz, 1846 | Jr., O. C. Wendell, Wm. Max- | Meridian Circle |
| Draper | well Reed, Wm. H. Pickering, | Observations |
| Clark, 1887 | John Ritchie, Jr., Observers | |
| Clark, 1888 | | |
| Clark | | |
| Clark, 1870 | | |
| Clark, 1885 | | |
| | | |
| Queen, 1888 | Edmund E. Read, Jr., Director | Solar Prominences |
| | A. B. Depuy, Observer | |
| Clark | Ormond Stone, Director; N. W. | Nebulæ |
| Kahler | Parrish, Frank Muller, Ob- | |
| | servers | |
| Brashear, 1891 | Geo. E. Hale, Director | Spectroscopy |
| | | |
| Merz & Mahler, 1843 | Jermain G. Porter, Director | Sidereal Motion |
| Fauth | | |
| Clark | | |
| Spencer | | Star Charts, Vari- |
| Schrœder | | able Stars, Minor |
| Steinhold | | Planets |
| Merz & Mahler, 1850 | Milton Updegraff, Director | Star Positions |
| | | |
| Clark, 1883 | Goodwin D. Swezey, Director | Student Work |
| Clark, 1881 | Rowley Patterson, Observer | |
| Clark, 1890 | Herbert A. Howe, Director | Work not yet be- |
| Brashear | | gun |
| Clark, 1862 | G. W. Hough, Director | Jupt, Double stars |
| 1888 | | Educational |

| *Location.* | *Owner.* | *Description.* |
|---|---|---|
| Galesburg, Ill. | Knox College Observatory | 6-in. Refractor |
| Geneva, N. Y. | Hobart College Observatory | 8.75-in. Refractor |
| Geneva, N. Y. | Smith Observatory | 10.12-in. Refractor |
| | | 9-in. Reflector |
| | | 5-in. Reflector |
| | | 4-in. Mer. Circle |
| Glasgow, Mo. | Morrison Observatory | 12.25-in. Refractor |
| | | 6-in. Mer. Circle |
| Greencastle, Ind. | McKim Observatory of the De Pauw University. | 9.5-Refractor |
| | | 4-in. Almucantar |
| Greenville, Pa. | Rev. John Peate, D. D. | 22-in. Reflector |
| | | 12.37-in. Silver-on-Glass Reflector |
| Grinnell, Ia. | Iowa College Observatory | 8-in. Refractor |
| Hamburgh, N. Y. | B. M. Fish | 7.33-in. Refractor |
| Hanover, N. H. | Shattuck Observatory of Dartmouth College | 9.25-in. Refractor |
| | | 4-in. Mer. Circle |
| Hartford, Conn. | High School | 9.4-in. Refractor |
| Haverford College, Pa. | Haverford College Observatory | 10-in. Refractor |
| | | 8.25-in. Refractor |
| | | 8.25-in. Newt. Refl. |
| | | 4-in. Mer. Circle |
| Hockessin, Del. | John G. Jackson | 6-in. Reflector |
| Hudson, O. | Western Reserve College | 4-in. Refractor |
| Jackson, Mich. | U. W. Lawton | 4-in. Refractor |
| Joliet, Ill. | Joliet High School | 4.5-in. Refractor |
| Lancaster, Pa. | Daniel Scholl Observatory of Franklin and Marshall College | 11-in. Refractor |
| Lewisburg, Pa. | Bucknell College Observatory | 10-in. Refractor |
| Lewiston, Me. | Bates College | 6.25-in. Refractor |
| Little Rock, Ark. | T. E. Murrell, M. D. | 6.5-in. Silver-on-Glass Reflector |
| Lyons, N. Y. | M. A. Veeder | 6-in. Refractor |
| Madison, Wis. | Washburn Observatory University of Wisconsin | 15.5-in. Refractor |
| | | 6-in. Refractor |
| | | 4.8-in. Mer. Circle |
| Middletown, Conn. | Wesleyan University | 12-in. Refractor |
| Mount Hamilton, Cal. | Lick Observatory of the University of California | 36-in. Refractor |
| | | 12-in. Refractor |
| | | 6.5-in. Refractor |
| | | 6.5-in. Mer. Circle |
| | | 4-in. Comet Seeker |
| | | 4-in. Transit |
| | | 4-in. Photoheliograph |
| Newburgh, N. Y. | Darwin W. Esmond | 4 in. Refractor |
| New Haven, Conn. | Winchester Observatory of Yale University | 28-in. Refractor |
| | | 8-in. Refractor |
| | | 6-in. Heliometer |
| New York, N. Y. | Columbia College Observatory | 13-in. Refractor |
| Northfield, Minn. | Goodsell Observatory of Carleton College | 16.2-in. Refractor |
| | | 8.25-in. Refractor |
| | | 4.8-in. Mer. Circle |
| | | 4.3-in. Refractor |
| Oakland, Cal. | Chabot Observatory | 8.5-in. Refractor |
| | | 4.12-in. Tran. Circle |
| Oakland, Cal. | Chas. Burckhalter | 10.5-in. Reflector |

| *Maker and Date.* | *Astronomers.* | *Special Work.* |
|---|---|---|
| Clark, 1879 | Edgar L. Larkin, Director | Educational |
| Fitz | H. L. Smith, Director | Educational |
| Clacey | Wm. R. Brooks, Director; Anna G. Brooks, Observer | Comet Seeking, Planets |
| Warner & Swasey | | |
| Clark | Carr W. Pritchett, Director | Planets |
| Sims | | Double Stars |
| Clark, 1885 | Wilbur V. Brown, Director | Educational |
| Clacey, 1883 | | |
| Peate, 1890 | | |
| Peate | John Peate, Director | |
| Clark | S. J. Buck | Educational |
| Clark, 1872 | B. M. Fish, Observer | Comet Seeking |
| Clark | | Educational |
| Clark, 1883 | | Educational |
| Clark, 1883 | Francis P. Leavenworth, Director; H. V. Gummere, Observer | Double Stars |
| Fitz, 1852 | | |
| Calver | | |
| Sims | | |
| Clark | U. W. Lawton, Observer | |
| Clark | A. H. Wagner, Director | |
| Clark | | Educational |
| Clark | Wm. C. Bartol, Director; Wm. G. Owner, Observer | Educational |
| Fitz | | |
| Brashear | | |
| Fitz | M. A. Veeder, Director | Solar Observations |
| Clark, 1878 | Geo. C. Comstock, Director; A. S. Flint, Observer | Star Places, Constants of Refraction |
| Clark | | |
| Repsold | | |
| Clark | | Educational |
| Clark, 1886 | Edward S. Holden, Director; S. W. Burnham, J. M. Schæberle, E. E. Barnard, Charles B. Hill, W. W. Campbell, Observers | Star Motions, Double Stars, Nebulæ, Spectroscopy, Comets |
| Clark, 1881 | | |
| Clark | | |
| Repsold, 1884 | | |
| Clark | | |
| Fauth, 1881 | | |
| Clark | | |
| Clark | Leonard Waldo, Director; Wm. L. Elkin, H. A. Newton, C. S. Hastings, Observers | Stellar Parallax, Meteorites |
| Grubb | | |
| Repsold | | |
| | John K. Rees, Director; C. H. Jacoby, Observer | Educational |
| Brashear, 1891 | Wm. W. Payne, Director; Herbert C. Wilson, Miss C. R. Willard, Observers | Star Positions, Celestial Photo raphy |
| Clark, 1876 | | |
| Repsold | | |
| Byrne | | |
| Clark | Chas. Burckhalter, Director | Educational |
| Fauth | | |
| Brashear | Chas. Burckhalter, Director | |

| *Location.* | *Owner.* | *Description.* |
|---|---|---|
| Oakland, Cal. | Dr. J. H. Wythe | 8.5-in. Reflector |
| Oakland, Cal. | F. G. Blinn | 5-in. Refractor |
| Oakland, Cal. | Mills College | 5-in. Refractor |
| Omaha, Neb. | Creighton College Observatory | 5-in. Refractor |
| Pasadena, Cal. | Pasadena Hotel | 4-in. Refractor |
| Philadelphia, Pa. | Central High School | 6-in. Refractor<br>4.5-in. Mer. Circle |
| Poughkeepsie, N. Y. | Vassar College Observatory | 12.25-in. Refractor<br>5-in. Refr. Portable |
| Princeton, N. J. | Halsted Observatory of Princeton University | 23 in. Refractor<br>9.5-in. Refractor<br>4-in. Mer. Circle |
| Providence, R. I. | Ladd Observatory of Brown University | 12-in. Refractor<br>4-in. Refractor |
| Providence, R. I. | Seagrave Observatory | 8.25-in. Refractor |
| Rochester, N. Y. | Warner Observatory | 16-in. Refractor<br>4.5-in. Com. Seeker |
| Salem, O. | I. W. Thompson | 4-in. |
| San Francisco, Cal. | Davidson Observatory | 6.4-in. Refractor |
| San Francisco, Cal. | Charles Goodall | 5-in. Refractor |
| San Francisco, Cal. | James Murphy | 4-in. Refractor |
| San Francisco, Cal. | Wm. M. Pierson | 8.5-in. Refl. 1890 |
| San José, Cal. | University of the Pacific | 6-in. Refractor |
| San Mateo, Cal. | St. Mathews Hall College | 8.5-in. Reflector |
| Saratoga Springs, N. Y. | Hathorn Observatory | 6-in. Refractor |
| South Bergen, N. J. | Henry Harrison | 5.5-in. Refractor |
| South Hadley, Mass. | Williston Observatory of Mount Holyoke Seminary | 8-in. Refractor |
| Stanford, Fla. | J. E. Ingraham | 4.5-in. Refractor |
| St. Charles, Mo. | Capt. Petitdedier | 12-in. Reflector |
| St. Louis, Mo. | Observatory of Washington University | 6.5-Refractor |
| St. Louis, Mo. | Dr. J. G. W. Steedman | 8-in. Reflector |
| Swarthmore, Pa. | Swarthmore College Observatory | 6-in. Refractor |
| Syracuse, N. Y. | Holden Memorial Observatory | 8-in. Refractor |
| Syracuse, N. Y. | H. P. Stark | 5.3-in. Refractor |
| Tarrytown, N. Y. | Chas. H. Rockwell | 6.4-in.<br>4-in. |
| Washington, D. C. | U. S. Naval Observatory | 26-in. Refractor<br>9.6-in. Refractor<br>8.5-in. Tran. Circle<br>5.3-in. Prime Vert. Transit<br>5-in. Transit<br>4-in. Mural Circle |
| Washington, D. C. | Georgetown College Observatory | 4.8-in. Refractor<br>4.5-in. Transit<br>4-in. Mer. Circle |
| Washington, D. C. | Smithsonian Physical Obs. | 20-in. Refractor |
| Waterville, Me. | Shannon Obs. of Colby University | |
| West Point, N. Y. | Observatory of the U. S. Military Academy | 12-in. Refractor<br>8-in. Tran. Circle |
| Williamstown, Mass. | Williams College Observatory | 4.8-in. Mer. Circle |
| Wilmington, Del. | Alfred G. DuPont | 12-in. Reflector<br>4.5-in. Refractor |
| Wilmington, Del. | Elwood Garrett | 8.5-in. Reflector |
| Wilmington, Del. | Geo. W. Humphrey | 6.5-Reflector |

| *Maker and Date.* | *Astronomers.* | *Special Work.* |
|---|---|---|
| Brashear | | |
| Clark | | |
| Stewart | Joseph Rigge, Director | Educational |
| Merz | | Educational |
| Ertel | | |
| Clark | Mary W. Whitney, Director | Educational |
| Clark | | |
| Clark | Charles A. Young, Director; Malcolm McNeill, Observer | Solar Physics, Comets |
| Clark | | |
| Brashear, 1891 | Winslow Upton, Director | |
| | Frank E. Seagrave, Director | Double Stars |
| Clark, 1881 | Lewis Swift, Director; Edward D. T. Swift, Observer | Nebulæ, Comet Seeking |
| Clark, 1885 | George Davidson, Director; Geo. F. Davidson, Thos. D. Davidson, Observers | Planets, Eclipses, Occultations |
| Clark | | |
| Clark | T. C. George, Director | Educational |
| Brashear | | |
| Clark, 1883 | F. J. del Corral, Observer | Planets |
| Byrne | Henry Harrison, Director; M. Paddock, Observer | Double Stars |
| Clark, 1881 | Miss Elizabeth M. Bardwell, Dir. | Educational |
| Clark, 1885 | H. S. Pritchett, Director; Alfred Ramel, Observer | Comets, Planets |
| Brashear, 1888 | J. G. W. Steedman, Director | |
| | S. J. Cunningham, Director | Educational |
| Clark, 1887 | H. A. Peck, Director | Educational |
| Spencer | | |
| Hastings | Chas. H. Rockwell, Director | Lunar Wave in Earth's Crust |
| Clacey | | |
| Clark, 1873 | Capt. F. V. McNair, Supt.; Asaph Hall, W. Harkness, J. R. Eastman, Edgar Frisby, L. J. Brown, A. N. Skinner, H. M. Paul, Asaph Hall, Jr., W. M. Brown, Geo. A. Hill, C. S. McCoy, Observers. | Planets, Satellites, Comets, Double Stars, Parallax |
| Merz & Mahler, 1845 | | |
| Pistor & Martins, '65 | | |
| Pistor & Martins, '45 | | |
| Ertel, 1844 | | |
| Simms, 1844 | | |
| Simms | John G. Hagen, Director; James F. Dawson, Observer | Variable Stars, Star Occultations |
| Ertel | | |
| Simms | | |
| Grubb | S. P. Langley, Director | |
| | Wm. A. Rogers, Director | |
| Clark, 1884 | Lt. Wallace Mott, Director | |
| Repsold, 1885 | | |
| Repsold | Truman H. Safford, Director | |
| Brashear | | |
| Clark | | |
| Brashear | | |
| Brashear, 1882 | | |

## THE CHAMBERLIN OBSERVATORY.

FOR THE MESSENGER.

The Chamberlin Observatory owes its existence to the munificence of Hon. H. B. Chamberlin, of Denver, who has erected the building at a cost of about $25,000, and has made contracts for the instrumental equipment. The site embraces nearly fourteen acres, situated at a distance of five miles from the business centre of Denver, at University Park, the seat of the University of Denver, of which it forms a department.

The building is constructed of a very hard sandstone taken from the Archalow quarries at Lyons, Colo. The facing of the walls, from the watertable up, is a soft, rich red sandstone from the same quarries. The pier which is to support the twenty-inch equatorial is built of dimension stone, and is sixteen feet square at the base, and twelve feet square at the top; its height is twenty-five feet, half of which is below the grade line. There are two other piers; one for the four-inch meridian-circle, and the other for the photographic measuring engine.

The basement has a special entrance in the rear and contains a work-shop, store-room, janitor's quarters, photographic room with dark closet and porcelain sinks, and boiler room. The floor is of cement, except close to the piers, where a three inch space is left, filled with loose sand.

The director's office, on the main floor, in the west wing, contains shelves for the working library, and a case of twenty-four drawers for miscellaneous pamphlets; it is adorned by a grate and mantel. The transit-room in the east wing contains a sandstone pier of unusual form; two heavy blocks of stone are surmounted by a cap connecting them. The roof-shutters are of iron, and each is opened in 5 seconds by a simple gearing. Adjoining the transit-room is the chronograph-room, the two being connected by a window through which the chronograph can be watched.

In the clock-room provision has been made for two clocks, which are to be suspended on small oak beams which have been built into the equatorial pier, and project through the partition surrounding it. Around each beam, where it comes through the partition, is a space filled with mineral

wool. Clock closets will be built around the clocks. On the main floor are also the reference library, a computing room, an instrument room and a lavatory.

The second story contains a computing room, a bed-room, three large closets, and the dome room, which is thirty-four feet in diameter, and is surmounted by an iron dome built upon the Hough system, by Mr. William Scherzer, of Chicago. It is equipped with the Cooke shutter, which is a vertical semicircle, one extremity of which rests on a pivot, while the other rides on a track tangent to the base-ring of the dome. This shutter is surmounted by a Globe ventilator, and is eminently satisfactory. The entire slit, which is five feet wide and extends from the horizon to a point thirty inches beyond the zenith, is uncovered at once.

The building faces southward, and measures sixty-five feet by fifty; it is heated by steam and wired for electric lighting.

The Students' Observatory, likewise presented by Mr. Chamberlin, is twenty-four feet by fourteen feet, and shelters the six-inch Saegmuller-Brashear equatorial, and the two-inch Saegmuller transit. The dome is of wood, covered with tin, and was built by Mr. F. A. Walter, of University Park. The instruments have been fairly tested, and have proven themselves to be excellent. The design of the equatorial is noteworthy for simplicity, beauty, and serviceability.

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## HOW TO MAKE GOOD MERIDIAN OBSERVATIONS.

T. H. SAFFORD.*

FOR THE MESSENGER.

### DIFFERENTIAL OR ZONE OBSERVATIONS.

The ordinary instrumental corrections are somewhat variable. The correction for level and azimuth can be readily transformed, by using Bessel's formulæ, into equatorial ($m$) and polar ($n$); and the variations of $n$ measured by observing known polars at the beginning and end of an evening's work. Those of $m$ can be readily obtained from the formula

* Williams College, Williamstown, Mass.

$$m = i \sec \varphi - n \tan \varphi$$

when $i$ is the inclination, measured by the spirit level or by a combination of known collimation and nadir observations or, what is in many cases equally convenient, can be joined with those of the clock-correction. In fact most Observatory clocks are subject to variations from their average rate from day to day quite comparable with those of the quantity $m$, so that the values of $dt + m$ are obtained at the beginning and end of an evening's work by quick moving stars, and are not separated in their application. This was in fact the practice of both Bessel and Struve, and of many other first rate observers.

The hourly variations, unaccounted for by clock-rate, of $dt + m$, and those of $n$, may amount to several hundredths of a second hourly during an evening's (or morning's) work and it is not safe, therefore, to neglect them; but always best to determine clock and instrumental error at intervals of two or three hours.

The great zones, observed between 1869 and the present time, under the direction of the Astronomische Gesellschaft by a co-operative effort on the part of astronomers in many European countries and in the United States, were so arranged by Argelander. The northern heavens were divided into zones usually of 5° breadth; each Observatory taking part was to observe all stars down to the magnitude 9.0 and all fainter which had been previously determined by certain meridian observers—Lalande, Bessel and others. The participants were in freedom to subdivide their zones or not as their convenience dictated. The zones were to be divided into portions of about an hour and a half in length; each to be preceded and followed by zero stars in the same average declination as the zone itself; and not more than 10° from it on either side. And the instrumental correction ($n$) was to be obtained by polar stars both before and after the zone if thought necessary. As, however, its influence was slight because the zones were narrow and the average declination of both determined and determining stars the same, this point was not very important.

Here is a sample zone: No. 13, Christiania, May 6, 1870. A. R. $12^h$ $51^m$ — $14^h$ $25^m$, Dec. 65° — 70° not subdivided:

ZERO STARS.

| | | | |
|---|---|---|---|
| 76 Ursæ Majoris | $12^h$ | $36^m$ | 63.4° |
| Gr. 2001 | 13 | 23 | 73.1 |
| $\alpha$ Draconis | 14 | 1 | 65.0 |
| Gr. 2125 | 14 | 28 | 60.8 |

Polaris sub polo for value of *n*.

or No. 162 1873, Dec. 10. A. R. $0^h$ $11^m$ — $1^h$ $25^m$, Dec. 65° — 69°.

ZERO STARS.

| | | | |
|---|---|---|---|
| $\beta$ Cassiopeiæ | $0^h$ | $2^m$ | 58.5° |
| Groomb 29 | 0 | 9 | 76.2 |
| Bradley 82 | 0 | 43 | 63.6 |
| 40 Cassiopeiæ | 1 | 28 | 72.4 |
| 43 Cassiopeiæ | 1 | 32 | 67.4 |

Polaris above for value of *n*.

The declinations, as well as the right ascensions, are reduced by the zero-stars, so that the nadir, if used at all, is only employed to indicate changes in the zero-points; and in general the observations are differential, the zero-stars being observed under nearly the same circumstances as the zone-stars themselves.

The result of this method is to eliminate very completely the peculiarities of the instrument.

| Chr. | H | Chr. ˢ | Chr. ″ | H ˢ | H ″ | H — Chr. ˢ | H — Chr. ″ |
|---|---|---|---|---|---|---|---|
| 13 | 51 | 24.36 | 52.0 | 24.42 | 52.8 | + 0.06 | + 0.8 |
| 23 | 96 | 32.65 | 22.3 | 32.84 | 21.8 | + 0.19 | — 0.5 |
| 25 | 100 | 51.62 | 58.3 | 51.37 | 57.8 | — 0.25 | — 0.5 |
| 30 | 117 | 5.99 | 8.8 | 4.96 | 7.0 | — 0.03 | — 1.8 |
| 38 | 163 | 37.71 | 36.9 | 37.91 | 38.3 | + 0.20 | + 1.4 |
| 39 | 164 | 46.01 | 50.5 | 46.10 | 51.1 | + 0.09 | + 0.6 |
| 56 | 233 | 48.26 | 54.6 | 48.36 | 54.1 | + 0.10 | — 0.5 |
| 62 | 284 | 45.58 | 49.5 | 45.50 | 50.3 | + 0.02 | + 0.8 |
| 78 | 331 | 14.13 | 17.7 | 13.94 | 18.2 | — 0.19 | + 0.5 |
| 88 | 402 | 21.59 | 52.1 | 21.50 | 52.8 | — 0.19 | + 0.7 |
| | | | | | Mean. | 0.000 | + 0.15″ |
| | | | | | P. E. 1 Diffr. | ± 0.118ˢ | ± 0.70″ |

I have given here a comparison between the first ten stars common to the Helsingfors and Christiania zones, as a sample taken quite at random. It will be seen that there is no constant difference which cannot be explained by casual errors; yet the Christiania zone (65° — 70°) was taken with a meridian circle, with an aperture of 4.3 inches, and the circle about 2.6 inches diameter was read by two ver-

niers, while the Helsingfors zone was observed with a transit instrument fitted with a divided arc of 24 degrees with a radius of 15 inches read by a single microscope. The flexure of the telescope of the latter instrument was very large, and the services of the former gave much trouble; but the outstanding errors seem to have been perfectly corrected by the differential method.

The probable difference in right-ascension is about the same as we should expect. Both observers used the eye-and-ear method, and observed these stars 2 or 3 times on 3 or 4 wires each; so that, after reduction from the parallel of 65° to the equator, we find the declination and right ascension to be observed with a probable error of not far from half a second of arc in either case.

Future zone observations are likely to be made in less quantity. There are not far from 150,000 stars included in the project now nearly completed; each star has been observed at least twice. The project extends from 80° north to 23° south declination; the region around the north pole was observed by Carrington, and has been more or less worked up by others, with a somewhat greater degree of completeness, all told; the required zero-points of the photographic survey will be less in number, as 6 stars to a plate 2° square means less than 70,000 stars in the whole sphere, or about a third as many for the same area. The future zone-observations will be made for photographic zero-points; hence probably greater accuracy (7 to 15 wires for each star and 2 microscopes in all cases) will be aimed at in the single observations. But on the other hand the quantity of work required is so large and the advantages of the differential method are so considerable, that it will doubtless be employed with the slight modification that few stars to a zone will be taken, but on more wires and with two microscopes.

Those observers on the Astronomische Gesellschaft's plan who were able to work most rapidly employed one microscope only. But in this case the bisection was made twice, on two successive division lines of the limb; and the repetition of the observation made on a different part of the circle. At Helsingfors, as before stated, the instrument had but one microscope; but the errors of all the divisions on

the limb of 24° were carefully determined by an ingenious process invented by Professor Krüger. Moreover the zero-point was always shifted from zone to zone by unclamping the divided arc and moving it to another position. My own participation in this great work was interrupted by the consequences of the great Chicago fire, after about two and a half years had been employed upon it. The Chicago meridian circle (now at Evanston) has an aperture of 6.4 inches. According to the formula which I employ for this purpose

$$5^{m}.0 \, . + 5 \log \text{aperture in English inches}$$

it is adequate to the observation (with full illumination) of stars down to the magnitude 9.0; with modified illumination of the field, stars of the magnitude 9.7 (called 9.4 or 9.5 in the Durchmusterung) can be taken with almost as much accuracy, if special pains be taken. But at Christiania, where the aperture was only 4.3 inches, the limit of the most accurate observation under average circumstances would be 8.9; 8.2 with full illumination; so that the astronomers there must have taken especial pains to pick up the faint stars on unusually transparent nights.

With wire-illumination of course much fainter stars can be taken; while the glass-scales which have been a good deal employed in this country seem to cut off about half a magnitude from the ordinary range of field illumination. That is to say, they reduce the effectiveness of the aperture nearly 37 per cent; or a 6-inch telescope with glass scales is no better than a 4¾-inch with field-illumination and spider lines.

In fact with the 8-inch Harvard College meridian circle and glass scales there seems to be difficulties in getting the fainter stars of the programme which are quite of the same order as those noticed by Argelander with 4.8 inches and spider-lines, with field-illumination. The next improvement to be made in zone-observations will be, I think, the use of 7th and perhaps 8th magnitude stars as zero-points; such stars to be carefully determined at several Observatories in considerable number. I shall have more to say about this in my next article; in which I shall also give a detailed account of Professor Boss's admirable zone, +1° to +5°, tak-at Albany.

## ON THE EFFICIENCY OF A SMALL INSTRUMENT.

GEORGE C. COMSTOCK.*

FOR THE MESSENGER.

In the *Description de l'Observatoire Astronomique Central de Poulkova* by F. G. W. Struve occurs the following passage prefixed to the description of the great vertical circle: "Many astronomers have found in their experience that small instruments furnish results which, comparatively speaking, are much more precise than those given by large ones, and this is especially true in the case of zenith distances. The two classes of instruments, being equally subject to the effect of atmospheric disturbances ,have their efficiency in some measure equalized by this circumstance. Nevertheless under the most favorable external conditions, where the large instruments possess all the advantage of greater magnifying power, and where the precision of the graduation is not nullified by the uncertainty of the pointings, small instruments have shown themselves comparatively superior to large ones."

Struve is not here considering the relative optical efficiency of small and large telescopes, which has been so frequently discussed in recent years, but their ability to furnish accurate numerical results in the determination of latitude, time, azimuth, etc., and my purpose in the present article is to add something by way of confirmation to the opinion above expressed. The Washburn Observatory has recently acquired a small universal instrument by Bamberg, of Berlin, which is used principally in the instruction of students in practical astronomy, and in connection with this use I have had occasion to study the instrument with some care to determine what measure of precision is attainable with it, and the numerical results cited below are the result of this study. The instrument consists essentially of a horizontal and vertical circle, each 175 $^{mm}$ in diameter, divided to 10′ and read by two micrometer microscopes to 5″, or by estimation to 0″.5. The telescope is a broken one of 36 $^{mm}$ aperture and 378 $^{mm}$ focal length, and is provided with an eye-piece giving a magnifying power of 36 diameters. As or-

* Director, Washburn Observatory, Madison, Wis.

iginally constructed the instrument was provided with a system of spider threads which I have removed and substituted for them a glass plate with ruled lines blackened by filling them with powdered graphite. The lines thus obtained are much finer than any spider threads I have ever seen, and are in every way preferable to them.

Taking up now the question of attainable precision we note that Foerster, who has made a careful investigation of a somewhat smaller instrument by the same maker, states that "the probable error of a single determination of altitude with the five-inch instrument can be reduced to one second of an arc," a statement which agrees very well with the results of my own experience, for I find from latitude observations made with the instrument above described that the probable error of a single zenith distance, the mean of a reading Circle Right and Circle Left, is $\pm 0''.8$, certainly a surprising degree of accuracy for an instrument which is small enough to be picked up and carried about in one's hands.

It is, however, in connection with time determinations that I possess the largest amount of data in regard to the efficiency of the instrument. For these determinations I have used exclusively the method of transits over the vertical of the pole star, Doellen's method with the formulæ slightly modified; employing a sidereal chronometer beating half seconds and observing the transits of the stars by eye and ear over five threads. Albrecht's formula for the probable error of an observed transit of a star over a single thread, which is in substantial agreement with the experience of the observers of the U. S. Coast Survey, is

$$v=\sqrt{a^2+\left(\frac{b}{u}\right)^2\sec^2\delta} \qquad a=0.07^s \qquad b=3.18^s$$

where $v$ is the magnifying power employed. This gives for an observation of an equatorial star with this instrument $v=\pm 0^s.113$, while from actual observation with the instrument I find the following values of this probable error, each value being derived without reduction to the equator from all the observations of a single night, and every night on which four or more stars were observed being included in the summary.

| Date. | No. of Stars. | P. E. of a Transit over a Single Thread. |
|---|---|---|
| 1891, April 3 | 4 | $\pm 0.07^s$ |
| June 8 | 4 | .08 |
| July 18 | 4 | .07 |
| " 30 | 5 | .04 |
| Aug. 4 | 6 | .06 |
| " 7 | 4 | .08 |
| " 13 | 4 | .07 |
| " 15 | 4 | .06 |
| Sept. 4 | 4 | .06 |

The mean of these results $\pm 0.066^s$ indicates a precision more than three times as great as that assigned by the formula, which is based upon observations made with larger instruments and greater magnifying power. A partial explanation of this difference may perhaps be found in the appearance of a bright star in a large telescope, a flaming body of light whose exact position cannot be determined as precisely as can that of a fainter star or the same star seen in a smaller telescope. It is also probable that the actual relation of magnifying power to precision of observation is not represented by the formula.

Perhaps the most striking illustration of the precision attainable with the instrument under consideration is furnished by the individual values of the chronometer correction furnished by the several stars observed on each night. These are given in the following table, which is not a selection of the most consistent results out of a series, but contains the chronometer correction given by every star observed by me with this instrument between June 8 and Sept. 4, 1891. An equal number of stars is observed in each position of the clamp and the collimation has been derived from the observations.

| June 8. | July 18. | July 30. | Aug. 4. | Aug. 7. | Aug. 13. | Aug. 15. | Sept. 4. |
|---|---|---|---|---|---|---|---|
| $-5.15^s$ | $-10.33^s$ | $-11.79^s$ | $-14.20^s$ | $-13.52^s$ | $-8.50^s$ | $-8.24^s$ | $-14.09^s$ |
| 5.00 | 10.40 | 11.79 | 14.17 | 13.52 | 8.48 | 8.20 | 14.16 |
| 5.10 | 10.29 | 11.74 | 14.18 | 13.64 | 8.49 | 8.29 | 14.12 |
| 5.03 | 10.44 | 11.73 | 14.20 | 13.62 | 8.51 | 8.23 | 14.18 |
| | | 11.81 | 14.14 | | | | |
| | | | 14.22 | | | | |
| $-5.07$ | $-10.36$ | $-11.77$ | $-14.18$ | $-13.58$ | $-8.50$ | $-8.24$ | $-14.14$ |

From the 35 residuals furnished by the above observations I find for the probable error of a chronometer correction from a single star $\pm 0.038^s$, while for the meridian circle of the Washburn Observatory, used in connection with a

chronograph, the corresponding probable error is $\pm 0.030$. In comparing the precision of the results furnished by these two instruments it should be borne in mind that the accuracy of the meridian circle time determinations depends upon the perfect determination of the collimation by instrumental means, while in the case of the smaller instrument the collimation is eliminated by reversal; and that wherever the time is required with great precision, as in the determination of longitude, this difference between the instruments gives a marked advantage to the reversible one.

The chronometer corrections contained in the above table will compare favorably with the corresponding quantities in any published longitude determination with which I am acquainted, and put in evidence not only the quality of the instrument but also the excellence of the method of determining time by means of an instrument mounted in the vertical of the pole star. It is to be regretted that American astronomers make but little use of so excellent a method concerning which we are tempted to say with Doellen that, under all circumstances where time is to be determined with a portable transit instrument, it is more advantageous to mount that instrument in the vertical of the pole star than to mount it in the meridian.

Washburn Observatory, September, 1891.

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## A NOTE ON THE DISTRIBUTION OF THE STARS.

W. H. S. MONCK.

FOR THE MESSENGER.

In former numbers of THE SIDEREAL MESSENGER I pointed out that, adopting the photometric scale and assuming the distribution of the stars to be uniform, the stars comprised in any half-magnitude ought to be (in round numbers) double that comprised in the preceding half-magnitude and equal to the entire number of brighter stars. Taking the Harvard and Oxford Photometries it appeared that this ratio was not realized anywhere except for the half-magnitude 2.0 to 2.5, but that for all magnitudes below 5.5 these Catalogues could not be regarded as complete. Taking,

however, Dr. Seeliger's count of the stars in the *Durschmusterung* and Schönfeld's southern extension of it, the theoretical ratio again appeared to be exceeded for the half-magnitudes 8.0 to 8.5 and 8.5 to 9.0. The half-magnitude 9.0 to 9.5 I omitted, because it was known that Argelander had classed many 10th magnitude stars as 9.5, that being the highest figure used by him. The number of stars from 5.5 to 6.0 did not appear in Seeliger's table, and the position of that half-magnitude was consequently left in doubt.

The recently published Harvard tables enable us to a certain extent to test Argelander's and Schönfeld's figures by the photometric scale. They are not indeed convenient for this purpose, because larger stretches were examined for the brighter stars in the D. M. than for the fainter ones. I recently, however, made a count of the stars in question confined to the stretches of the sky in which all stars rated up to 9.0 in the D. M. were photometrically measured; and though the following figures may not be strictly accurate I have no doubt that they are so substantially:

| Magnitudes. | No. of Stars Measured at Harvard. | Magnitudes. | No. of Stars Measured at Harvard. |
|---|---|---|---|
| Brighter than 5.0 | = 57 | 7.0 to 7.5 | = 565 |
| 5.0 to 5.5 | = 49 | 7.5 to 8.0 | = 973 |
| 5.5 to 6.0 | = 98 | 8.0 to 8.5 | = 1654 |
| 6.0 to 6.5 | = 200 | 8.5 to 9.0 | = 2871 |
| 6.5 to 7.0 | = 334 | | |

The first four divisions here approach the theoretic ratio very closely, thus apparently indicating a relative thickening of the stars between 5.5 and 6.5 similar to that between 2.0 and 2.5 but less marked. But from this point onwards the theoretical ratio is not realized, and the conclusion drawn from the D. M., as to its being exceeded between 8.0 and 8.5, seems contradicted. As regards the interval 8.5 to 9.0 the question is more doubtful, for the present Harvard table is no doubt incomplete. All stars up to 9.0 in the D. M. in these stretches were measured, but there are probably many stars rated above 9.0 in the D. M. which would rate below 9.0 if measured photometrically.

In order to see whether there was any considerable difference in the star-distribution in different parts of the sky I compared the stretches from 0° to 20° N. (inclusive) with those from 0° to 20° S. inclusive. The northern stretches

seem to have embraced a slightly larger portion of the sky, which I believe accounts for its apparent greater richness in stars. The figures are as follow:

| Magnitudes. | No. of Stars N. | No. of Stars S |
|---|---|---|
| Over 5.0 | 17 | 20 |
| 5.0 to 5.5 | 11 | 12 |
| 5.5 to 6.0 | 29 | 16 |
| 6.0 to 6.5 | 62 | 54 |
| 6.5 to 7.0 | 109 | 74 |
| 7.0 to 7.5 | 146 | 143 |
| 7.5 to 8.0 | 278 | 222 |
| 8.0 to 8.5 | 474 | 419 |
| 8.5 to 9.0 | 846 | 758 |

These figures do not present any differences which seem inexplicable on the doctrine of chances when only a small portion of the sky is examined. The greater richness of the southern region in the stars brighter than 5.0, however, appears to be borne out as we go farther north. Thus for the stretches from 64° N. to the pole, where the effect of the Galaxy is trifling, I find

| Magnitudes. | No. of Stars. | Magnitudes. | No. of Stars. |
|---|---|---|---|
| Brighter than 5.0 | 2 | 7.0 to 7.5 | 76 |
| 5.0 to 5.5 | 8 | 7.5 to 8.0 | 127 |
| 5.5 to 6.0 | 11 | 8.0 to 8.5 | 206 |
| 6.0 to 6.5 | 28 | 8.5 to 9.0 | 331 |
| 6.5 to 7.0 | 47 | | |

These figures seem rather opposed to the theory, which is current in many quarters, that the brighter stars are distributed pretty equably everywhere, while the fainter ones are congregated in and around the Galaxy. But we shall not be able to reach any decisive conclusion so long as our measurements are confined to selected stretches instead of embracing the entire sky. Laborious as the latter process will be it must, I think, ultimately be undertaken; but in the meantime less laborious photometric measurements (whether in connection with photography or with Professor Menchin's photo-electric discoveries) may be substituted for those of Professor Pickering.

In conclusion it may be desirable to explain briefly what the theoretic ratio means. It does not imply that the stars are uniformly distributed in all directions. Suppose, for instance, that all space is divided into a number of cones, each having its vertex at the spectator, the theoretic ratio would be realized if the distribution in each cone was uniform, al-

though one cone might be much more thickly packed with stars than another. It would also be realized if, as we move outward from the spectator, the changes of density in these cones were of a compensating character. But the theoretic ratio might not be realized if space was divided into a rich region and a poor region, although the distribution of the stars was sensibly uniform within each region. If the shape of the rich region was such that when we drew a number of spheres round the earth as centre with ever-increasing radii a constantly decreasing proportion of the spherical surface lay within the rich region, the theoretical number of stars would never be realized—at least unless we chanced on an unusual number of rich clusters at a particular stage. And I think few persons will assign to the Galaxy a spreading shape which would occupy an equal proportion of the surface of each successive sphere. The first question which we have to solve, however, seems to me to be this: Are we *in* the Galaxy—the sun being one of the Galactic stars situated in a comparative vacuity—and if not, at what distance do our successive spheres first encounter it? If we are outside of the Galaxy there ought apparently to be an increase in the number of stars beyond the theoretic ratio at the distance where the first serious encounter of the Galaxy with one of our successive spheres takes place. But circumstances might modify this result. If, for instance, as some astronomers believe, the stars in the Galaxy are considerably smaller (on the average) than those elsewhere, the reverse effect might first take place. Suppose that at the average distance of a 7th magnitude star we cut for the first time pretty deeply into the Galaxy, and that the stars from their smaller size were (on the average) of the 8th magnitude, we would seem to have cut not into a rich region but into a vacuity; and the stars of the 7th magnitude, instead of exceeding the theoretical number, would fall short of it. The figures which I have given do not, however, seem to afford decisive indications of our cutting into the Galaxy at *any* distance, and therefore the conclusion seems to be either that the sun is in the Galaxy or that the distance of the Galaxy from the sun is greater than that of an average star of the 9th magnitude. An absorption of light, however, either by the ether or by meteors

would modify the phenomena; and if meteors exist in space in anything like the numbers which the Meteoritic Hypothesis supposes the loss of light from this cause must be very considerable.

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## RELATIVE MOTIONS OF THE SPOTS AND MARKINGS ON THE SURFACE OF JUPITER, FROM MICROMETRICAL OBSERVATIONS MADE AT THE LICK OBSERVATORY.

E. E. BARNARD.

FOR THE MESSENGER.

In the August number of THE MESSENGER Professor Hough has an interesting note about some of the markings on Jupiter. In speaking of the southern white spots he says "These spots . . . give a rotation period approximately the same as the great red spot." I have made quite a number of observations of several of these objects with the 12-inch equatorial, and find that their rotation period is considerably shorter than that of the great red spot. Their longitudes diminish 0°.57 ($56^s$) daily, or $23^s$ at each rotation of Jupiter, while the red spot is approximately stationary. One of these white spots is now passing the red spot closely south of it.

Following are its longitudes on two of the dates of observation:

| | | |
|---|---|---|
| 1891 | Aug. 12 | $\lambda = 8°.6$ |
| | Aug. 27 | $\lambda = 357°.4$ |

Following are two observations of the great red spot for comparison:

| | | |
|---|---|---|
| 1891 | June 5 | $\lambda = 3°.1$ |
| | Sept. 3 | $\lambda = 3°.3$ |

I have also followed another of these white spots for some time. It is about 1½″ in diameter, and is surrounded by a dark circular shade. It has continued permanent for over a month without any special change. Following are two observations of it:

| | | |
|---|---|---|
| 1891 | July 27 | $\lambda = 125°.9$ |
| | Aug. 25 | $\lambda = 110°.0$ |

I have observed the new red spot, mentioned by Professor Hough, since its formation last year. It was first dark and

then turned red. Following are its longitudes at two of the observations:

| | | | |
|---|---|---|---|
| 1891 | July | 25 | $\lambda = 177^\circ.2$ |
| | Sept. | 7 | $\lambda = 151^\circ.5$ |

Its period is quite different from that of the old red spot, being shorter, and does not materially differ from that of the southern white spots, one of which has been attached to its preceding end since last year. The present motion will bring it around in conjunction again with the great red spot in May next, when it will pass close south of that object.

It is now the most conspicuous marking on the planet. There is a similar spot—a little longer and not so definite—preceding the great red spot a short distance.

These two objects, with the bright spots, are situated on a belt which passes just free of the southern edge of the great red spot. There are, however, some small bright spots south of this belt.

Quite a number of small black spots appeared, at the close of the observations last year, on the first narrow belt about 9″ north. They were exceedingly small and black—like a row of needle points strung along the belt. Some of them have enlarged greatly and are now becoming quite noticeable.

The small dark spots on the north edge of the equatorial belt, mentioned by Professor Hough, were first seen by me on April 26, 1890, and have been carefully followed ever since. They were at first as black and round as the shadows of the satellites, but later became red. Their periods, though shorter than that of the great red spot, are somewhat longer than those of the southern white spots. A series of micrometer measures was begun last year upon two of these which were then about on the same meridian with the red spot. They have been gradually approaching each other, the distance between them having diminished about 3″ since last year. They are now about 6″ apart. There were six, in all, of these small spots and their latitudes were exactly the same.

Following are observatians of the first of the two mentioned:

| | | | |
|---|---|---|---|
| 1890 | April | 26 | $\lambda = 348^\circ.4$ |
| 1891 | Aug. | 9 | $\lambda = 253^\circ.9$ |
| | Sept. | 7 | $\lambda = 248^\circ.1$ |

The longitudes are derived with the aid of Dr. Marth's invaluable Ephemeris (System II.) in *Monthly Notices*.

There has been quite a change in the equatorial regions since last year. A broad white band now occupies the space between the northern and southern equatorial belts.

I have already called attention to the increased intensity of the great red spot, in a communication to the *Monthly Notices* of the R. A. S.

A remarkable feature connected with the red spot is the persistence of the bay formed north following it by the southern equatorial belt. This has been a prominent feature for quite a number of years and is intimately associated with the history of the spot. It was entirely absent in 1880, though present in 1879.

On Sept. 4, 1891, the first satellite was observed in transit, overlapping its shadow on the south following side. The shadow appeared as a crescent. With the great telescope, *the satellite itself appeared perfectly round, with no mark upon it*.

Mt. Hamilton, Sept. 9th, 1891.

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## CURRENT CELESTIAL PHENOMENA.

### THE PLANETS.

*Mercury* will be at superior conjunction with the sun on Oct. 27. During the first two weeks of this month the planet will be in good position for daylight observations in the early part of the day. The phase will be gibbous, seven-tenths of the disk being illuminated on Oct. 3, and the whole on Oct. 27.

*Venus* is now "evening planet" but will for this month be too close to the solar rays to be easily seen. Daylight observations in the afternoon may be of value in the study of the markings on the planet and its rotation period. With our 16-inch telescope we have, on several occasions, examined the planet in full sunlight, with excellent definition, and, although there were very faint dusky shadings, they were so indefinite and illusory that it seemed hopeless to identify them.

*Mars* is behind the sun and will not be observable during this year.

*Jupiter* is now a splendid object in large or small telescopes. Crossing the meridian between ten and eleven in the evening, he is the most conspicuous object in the sky, excepting, of course, the moon. With a small telescope the four moons and three or four principal belts can be seen. With a large telescope the belts become more numerous, from six to ten, their color

is more pronounced and vastly more of detail is seen in them. The great red spot is quite conspicuous now, its color decidedly pink, the central area changing from white to pink. The belt just south of the spot (above it in an inverting telescope) is considerably darker than the spot and seems now to crowd upon it. Whether one overlaps the other it seems impossible to decide. A portion of this belt preceding the red spot by a distance equal to about one quarter of Jupiter's diameter, is very deep red and now more conspicuous than the great spot. Several observers have called attention to this new red spot. A number of small spots along the edge of the second principal belt north of Jupiter's equator, which, with low powers, appear almost round and black, become, with higher powers, elongated patches of deep red. Six of these were counted on the edge of one belt and three on another on the night of Sept. 3, 1891, by Professor Payne and Dr. Wilson.

The attention of observers is called to a very narrow belt midway between the two principal belts of Jupiter, almost exactly on the equator of the planet, which is not shown in drawings made in other years. It was sketched at Goodsell Observatory Aug. 31 at 12:30 and Sept. 3, 12:15.

*Saturn* is "morning star," rising an hour and a half before the sun. The rings are now invisible, the sun shining on the south side of the rings, while we look upon the north side. On Oct. 30 the sun will begin to illuminate the north side of the rings so that they should then become visible. The planet will be in such an unfavorable position for observations that probably little can be seen of the phenomena attending the gradual illumination and opening of the rings.

*Uranus* will be at conjunction with the sun Oct. 24, so that he is out of view.

*Neptune* may be seen after nine o'clock, the best hours being from midnight to four in the morning. He is almost exactly north of the bright red star Aldebaran at a distance of a little less than four degrees, in the constellation of Taurus.

| Date. 1891. | R. A. h m | Decl. ° ′ | Rises. h m | Transits. h m | Sets. h m |
|---|---|---|---|---|---|
| | | MERCURY. | | | |
| Oct. 25 | 13 54.5 | − 10 58 | 6 20 A. M. | 11 39.2 A. M. | 4 59 P. M. |
| Nov. 5 | 15 02.8 | − 17 46 | 7 14 " | 12 04.1 P. M. | 4 55 " |
| 15 | 16 06.2 | − 22 25 | 7 59 " | 12 27.9 P. M. | 4 56 " |
| | | VENUS. | | | |
| Oct. 25 | 14 37.9 | − 14 53 | 7 19 A. M. | 12 22.1 P. M. | 5 25 P. M. |
| Nov. 5 | 15 32.7 | − 19 05 | 7 50 " | 12 33.9 " | 5 18 " |
| 15 | 16 24.8 | − 21 59 | 8 16 " | 12 46.6 " | 5 17 " |
| | | MARS. | | | |
| Oct. 25 | 12 10.4 | + 0 06 | 3 52 A. M. | 9 55.5 A. M. | 3 59 P. M. |
| Nov. 5 | 12 35.8 | − 2 41 | 3 45 " | 9 37.7 " | 3 31 " |
| 15 | 12 59.3 | − 5 10 | 3 39 " | 9 21.6 " | 3 05 " |
| | | JUPITER. | | | |
| Oct. 25 | 22 41.7 | − 9 47 | 3 00 P. M. | 8 25.0 P. M. | 1 50 A. M. |
| Nov. 5 | 22 41.3 | − 9 47 | 2 17 " | 7 41.3 " | 1 06 " |
| 15 | 22 42.2 | − 9 39 | 1 38 " | 7 02.8 " | 12 28 " |

| Date. 1891. | R. A. h m | Decl. ° ′ | Rises. h m | Transits. h m | Sets. h m |
|---|---|---|---|---|---|
| SATURN. | | | | | |
| Oct. 25 | 11 46.6 | + 3 37 | 3 14 A. M. | 9 31.6 A. M. | 3 49 P. M. |
| Nov. 5 | 11 50.8 | + 3 11 | 2 37 " | 8 52.6 " | 3 09 " |
| 15 | 11 54.3 | + 2 50 | 2 02 " | 8 16.8 " | 2 31 " |
| URANUS. | | | | | |
| Oct. 25 | 13 59.0 | − 11 38 | 6 27 A. M. | 11 43.8 A. M. | 5 00 P. M. |
| Nov. 5 | 14 01.8 | − 11 53 | 5 48 " | 11 03.3 " | 4 19 " |
| 15 | 14 04.1 | − 12 05 | 5 11 " | 10 26.2 " | 3 41 " |
| NEPTUNE. | | | | | |
| Oct. 25 | 4 28.7 | + 20 08 | 6 42 P. M. | 2 10.6 A. M. | 9 39 A. M. |
| Nov. 5 | 4 27.3 | + 20 05 | 5 58 " | 1 26.3 " | 8 54 " |
| 15 | 4 26.2 | + 20 03 | 5 18 " | 12 45.9 " | 8 14 " |
| THE SUN. | | | | | |
| Oct. 25 | 13 59.5 | − 12 12 | 6 29 A. M. | 11 44.1 A. M. | 5 00 P. M. |
| Nov. 5 | 14 42.4 | − 15 46 | 6 44 " | 11 43.7 " | 4 44 " |
| 15 | 15 22.9 | − 18 34 | 6 57 " | 11 44.7 " | 4 32 " |

## Jupiter's Satellites.

| Date | Central Time. h m | | Date | Central Time. h m | |
|---|---|---|---|---|---|
| Oct. 16 | 12 19 A. M. | II Ec. Re. | Oct. 30 | 12 25 A. M. | II Oc. Dis. |
| 17 | 5 32 P. M. | II Tr. Eg. | | 6 13 P. M. | III Sh. In. |
| | 7 28 " | II Sh. Eg. | | 7 09 " | I Ec. Re. |
| 19 | 8 01 " | III Oc. Dis. | | 9 33 " | III Sh. Eg. |
| | 11 26 " | III Oc. Re. | 31 | 7 25 " | IV Oc. Re. |
| 20 | 12 13 A. M. | III Ec. Dis. | | 7 31 " | II Tr. In. |
| | 12 58 " | I Oc. Dis. | | 9 52 " | II Sh. In. |
| | 10 07 P. M. | I Tr. In. | | 10 24 " | II Tr. Eg. |
| | 11 09 " | I Sh. In. | Nov. 1 | 12 43 A. M. | II Sh. Eg. |
| 21 | 12 26 A. M. | I Tr. Eg. | 2 | 6 51 P. M. | II Ec. Re. |
| | 1 27 " | I Sh. Eg. | 4 | 11 06 " | I Oc. Dis. |
| | 7 26 P. M. | I Oc. Dis. | 5 | 8 14 " | I Tr. In. |
| | 10 44 " | I Ec. Re. | | 9 28 " | I Sh. In. |
| 22 | 5 37 " | I Sh. In. | | 10 33 " | I Tr. Eg. |
| | 6 53 " | I Tr. Eg. | | 11 46 " | I Sh. Eg. |
| | 7 55 " | I Sh. Eg. | 6 | 5 11 " | III Tr. In. |
| | 10 01 " | II Oc. Dis. | | 5 34 " | I Oc. Dis. |
| 23 | 5 13 " | I Ec. Re. | | 8 38 " | III Tr. Eg. |
| | 5 31 " | III Sh. Eg. | | 9 04 " | I Ec. Re. |
| | 7 08 " | IV Sh. In. | | 10 15 " | III Sh. In. |
| | 10 54 " | IV Sh. Eg. | 7 | 5 01 " | I Tr. Eg. |
| 24 | 5 04 " | II Tr. In. | | 6 15 " | I Sh. Eg. |
| | 7 14 " | II Sh. In. | | 10 00 " | II Tr. In. |
| | 7 57 " | II Tr. Eg. | 9 | 5 06 " | IV Sh. Eg. |
| | 10 05 " | II Sh. Eg. | | 9 28 " | II Ec. Re. |
| 26 | 11 37 " | III Oc. Dis. | 11 | 4 40 " | II Sh. Eg. |
| 27 | 11 56 " | I Tr. In. | 12 | 10 06 " | I Tr. In. |
| 28 | 1 04 A. M. | I Sh. In. | | 11 24 " | I Sh. In. |
| | 9 15 P. M. | I Oc. Dis. | 13 | 7 26 " | I Oc. Dis. |
| 29 | 12 40 A. M. | I Ec. Re. | | 9 00 " | III Tr. In. |
| | 6 24 P. M. | I Tr. In. | | 11 00 " | I Ec. Re. |
| | 7 33 " | I Sh. In. | 14 | 4 34 " | I Tr. In. |
| | 8 43 " | I Tr. Eg. | | 5 53 " | I Sh. In. |
| | 9 51 " | I Sh. Eg. | | 6 53 " | I Tr. Eg. |
| | | | | 8 11 " | I Sh. Eg. |
| | | | 15 | 5 29 " | I Ec. Re. |

### Configuration of Jupiter's Satellites at 10 p. m., for an Inverting Telescope.

| Date | Configuration | Date | Configuration | Date | Configuration |
|---|---|---|---|---|---|
| Oct. 16 | 3 ○ 1 2 4 | Nov. 1 | 3 2 ○ 1 4 | Nov. 16 | 3 4 1 ○ ● |
| 17 | 3 1 2 ○ 4 | 2 | 1 3 ○ 2 4 | 17 | ○ 3412 |
| 18 | 3 2 ○ 1 4 | 3 | ○ 1234 | 18 | 1 2 ○ 4 3 |
| 19 | 1 ○ 2 4● | 4 | 2 1 ○ 3 4 | 19 | 2 ○ 1 3 4 |
| 20 | ○ 1234 | 5 | 2 ○ 3 4♃ | 20 | 1 ○ 3 2 4 |
| 21 | 2 ○ 3 4● | 6 | ● ○ 2 4♃ | 21 | 3 ○ 2 4♃ |
| 22 | 1 2 ○ 3 4 | 7 | 3 1 ○ 2 4 | 22 | 3 2 ○ 1 4 |
| 23 | 3 4 ○ 1 2 | 8 | 3 2 ○ 4 1 | 23 | 3 1 2 ○ 4 |
| 24 | 3 4 1 2 ○ | 9 | 4 3 1 ○ 2 | 24 | ○ 3142 |
| 25 | 4 3 2 ○ 1 | 10 | 4 ○ 1 3 2 | 25 | 1 2 ○ 3 ♃ |
| 26 | 4 1 3 ○ 2 | 11 | 4 1 2 ○ 3 | 26 | 4 2 ○ 1 3 |
| 27 | 4 ○ 1 2 3 | 12 | 4 2 ○ 1 3 | 27 | 4 1 ○ 2 3 |
| 28 | 4 2 1 ○ 3 | 13 | 4 1 ○ 3 2 | 28 | 4 3 ○ 1 2 |
| 29 | 4 2 ○ 3 4 | 14 | 4 3 1 ○ 2 | 29 | 4 3 2 ○ ● |
| 30 | 4 3 ○ 1 2 | 15 | 3 4 2 ○ 1 | 30 | 4 3 2 1 ○ |
| 31 | 3 1 ○ 4 4 | | | | |

### Approximate Central Times when the Great Red Spot passes the Central Meridian of Jupiter.

| Date | h | m | | Date | h | m | | Date | h | m | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Oct. 5 | 9 | 09 | P. M. | Oct. 19 | 10 | 41 | P. M. | Nov. 3 | 12 | 11 | A. M. |
| 6 | 5 | 00 | " | 20 | 6 | 32 | " | 3 | 8 | 02 | P. M. |
| 7 | 10 | 47 | " | 22 | 12 | 19 | A. M. | 4 | 3 | 53 | " |
| 8 | 6 | 38 | " | 22 | 8 | 10 | P. M. | 5 | 9 | 10 | " |
| 9 | 12 | 26 | A. M. | 24 | 1 | 51 | A. M. | 6 | 5 | 31 | " |
| 10 | 8 | 17 | P. M. | 24 | 9 | 48 | P. M. | 7 | 11 | 18 | " |
| 11 | 4 | 08 | " | 25 | 5 | 39 | " | 8 | 7 | 10 | " |
| 12 | 9 | 55 | " | 26 | 11 | 26 | " | 9 | 3 | 01 | " |
| 13 | 5 | 46 | " | 27 | 7 | 17 | " | 10 | 8 | 48 | " |
| 14 | 11 | 33 | " | 29 | 1 | 04 | " | 11 | 4 | 39 | " |
| 15 | 7 | 26 | " | 29 | 8 | 55 | " | 12 | 10 | 26 | " |
| 17 | 1 | 12 | A. M. | 30 | 4 | 46 | " | 13 | 6 | 17 | " |
| 17 | 9 | 03 | P. M. | 31 | 10 | 33 | " | 15 | 12 | 04 | A. M. |
| 18 | 4 | 54 | " | Nov. 1 | 6 | 24 | " | 15 | 7 | 55 | P. M. |

### Occultations Visible at Washington.

| Date. | Star's Name. | Magnitude. | IMMERSION. Wash. Mean T. h m | IMMERSION. Angle f'm N. P't. ° | EMERSION. Wash. Mean T. h m | EMERSION. Angle f'm N. P't. ° | Duration. h m |
|---|---|---|---|---|---|---|---|
| Oct. 5 | $\alpha^2$ Libræ | 2.9 | 4 10 | 119 | 5 30.1 | 291 | 1 20 |
| 10 | B. A. C. 6666 | 5.8 | 8 50 | 165 | Star 0.1′ S. of moon's limb. | | |
| 12 | 35 Capricorni | 6.2 | 7 11 | 54 | 8 29.6 | 255 | 1 19 |
| 12 | 37 Capricorni | 6.0 | 12 02 | 18 | 12 45.0 | 288 | 0 43 |
| 19 | 56 Tauri | 6.0 | 16 58 | 159 | 17 05.6 | 172 | 0 07 |
| 20 | 103 Tauri | 6.0 | 10 05 | 50 | 11 02.9 | 270 | 0 58 |
| Nov. 14 | $\sigma$ Arietis | 5.5 | 15 49 | 51 | 16 43.5 | 269 | 0 55 |
| 15 | 13 Tauri | 5.7 | 12 23 | 333 | Star 0.6′ N. of moon's limb. | | |

### Phases and Aspects of the Moon.

| | | Central Time. d | h | m | |
|---|---|---|---|---|---|
| Perigee | Oct. | 16 | 11 | 24 | A. M. |
| Full Moon | " | 17 | 7 | 45 | A. M. |
| Last Quarter | " | 24 | 7 | 56 | A. M. |
| Apogee | " | 28 | 10 | 42 | P. M. |
| New Moon | Nov. | 1 | 12 | 33 | P. M. |
| First Quarter | " | 9 | 2 | 46 | A. M. |
| Perigee | " | 13 | 7 | 12 | P. M. |
| Full Moon | " | 15 | 6 | 16 | P. M. |

### Minima of Variable Stars of the Algol Type.

**U CEPHEI.**

R. A. .............. $0^h\ 52^m\ 32^s$
Decl. .............. $+81°\ 17'$
Period .......... $2d\ 11^h\ 50^m$

| | |
|---|---|
| Oct. 17 | 7 P. M. |
| 22 | 7 " |
| 27 | 7 " |
| Nov. 1 | 6 " |
| 6 | 6 " |
| 11 | 6 " |

**ALGOL.**

R. A. ............. $3^h\ 01^m\ 01^s$
Decl. ............. $+40°\ 32'$
Period .......... $2d\ 20^h\ 49^m$

| | |
|---|---|
| Oct. 25 | 3 A. M. |
| 27 | midn. |
| 30 | 9 P. M. |
| Nov. 2 | 6 P. M. |
| 14 | 5 A. M. |

**λ TAURI.**

R.A. ............... $3^h\ 54^m\ 35^s$
Decl. .............. $+12°\ 11'$
Period ......... $3d\ 22^h\ 52^m$

| | |
|---|---|
| Oct. 11 | 11 P. M. |
| 21 | 9 " |

**λ TAURI, CONT.**

| | |
|---|---|
| Oct. 25 | 8 P. M. |
| 29 | 7 " |
| Nov. 2 | 6 " |
| 6 | 5 " |

**R CANIS MAJ.**

R. A. ........... $7^h\ 14^m\ 30^s$
Decl. ............... $-16°\ 11'$
Period $1d\ 03^h\ 16^m$

| | |
|---|---|
| Oct. 17 | 5 A. M. |
| 23 | midn. |
| 24 | 3 A. M. |
| 25 | 6 " |
| Nov. 2 | 2 " |
| 3 | 5 " |
| 10 | 1 " |
| 11 | 4 " |

**S ANTLIAE.**

R. A. ........... $9^h\ 27^m\ 30^s$
Decl ............ $-\ 28°\ 9'$
Period ........ $0d\ 07^h\ 47^m$

| | |
|---|---|
| Oct. 16 | 6 A. M. |
| 17 | 5 " |
| 18 | 5 " |
| 19 | 4 " |

**S. ANTLIÆ, CONT.**

| | |
|---|---|
| Oct. 20 | 3 A. M. |
| 28 | 6 " |
| 29 | 6 " |
| 30 | 5 " |
| 31 | 5 " |
| Nov. 1 | 4 " |
| 2 | 4 " |
| 3 | 3 " |
| 9 | 6 " |
| 10 | 5 " |
| 11 | 4 " |
| 12 | 4 " |
| 13 | 3 " |

**Y. CYGNI.**

R. A. .......... $20^h\ 47^m\ 40^s$
Decl. ............... $+34°\ 15'$
Period ........ $1d\ 11^h\ 57^m$

| | |
|---|---|
| Oct. 11 | midn. |
| 19 | " |
| 22 | " |
| 25 | " |
| 28 | " |
| 31 | " |
| Nov. 3 | 11 P. M. |
| 6 | 11 " |
| 9 | 11 " |
| 12 | 11 " |
| 15 | 11 " |

## COMET NOTES.

*Ephemeris of the Temple-Swift Periodic Comet.*

(Continued from page 367.)

| 1891 | App. R. A. h m s | App. Decl. ° ′ | log Δ | Ab. T. m s | $\frac{1}{r^2 \Delta^2}$ |
|---|---|---|---|---|---|
| Oct. 16 | 21 10 48 | + 6 6.4 | | | |
| 18 | 21 12 49 | + 6 43.9 | 9.4512 | 2 21 | 9.54 |
| 20 | 21 15 13 | + 7 23.4 | | | |
| 22 | 21 18 00 | + 8 04.8 | 9.4353 | 2 16 | 10.54 |
| 24 | 21 21 12 | + 8 43.3 | | | |
| 26 | 21 24 50 | + 9 34.0 | 9.4189 | 2 11 | 11.64 |
| 28 | 21 28 56 | + 10 22.2 | | | |
| 30 | 21 33 30 | + 11 12.8 | 9.4021 | 2 06 | 12.83 |
| Nov. 1 | 21 38 35 | + 12 05.8 | | | |
| 3 | 21 44 11 | + 13 01.6 | 9.3851 | 2 01 | 14.09 |
| 5 | 21 50 21 | + 13 59.9 | | | |
| 7 | 21 57 07 | + 15 00.9 | 9.3683 | 1 56 | 15.41 |
| 9 | 22 04 31 | + 16 04.2 | | | |
| 11 | 22 12 34 | + 17 10.1 | 9.3520 | 1 52 | 16.71 |
| 13 | 22 21 20 | + 18 18.0 | | | |
| 15 | 22 30 48 | + 19 27.7 | 9.3370 | 1 48 | 17.93 |

### *Ephemeris of Encke's Comet for 1891.*

(Continued from page 368.)

| | App. R. A. h m s | App. Decl. ° ′ | log $r$ | log $\Delta$ | Ab. T. |
|---|---|---|---|---|---|
| Oct. 6 | 11 20 36 | + 9 42.0 | 9.6659 | 0.0159 | 8 36 |
| 7 | 11 27 55 | + 8 27.2 | 9.6503 | 0.0223 | |
| 8 | 11 35 12 | + 7 11.8 | 9.6347 | 0.0289 | 8 52 |
| 9 | 11 42 29 | + 5 56.0 | 9.6191 | 0.0357 | |
| 10 | 11 49 45 | + 4 39.8 | 9.6042 | 0.0427 | 9 09 |
| 11 | 11 57 02 | + 3 23.2 | 9.5897 | 0.0498 | |
| 12 | 12 04 20 | + 2 6.4 | 9.5762 | 0.0570 | 9 27 |
| 13 | 12 11 40 | + 0 49.4 | 9.5627 | 0.0642 | |
| 14 | 12 19 03 | − 0 27.6 | 9.5531 | 0.0713 | 9 47 |
| 15 | 12 26 30 | − 1 44.4 | 9.5444 | 0.0783 | |
| 16 | 12 34 00 | − 3 0.9 | 9.5377 | 0.0853 | 10 06 |
| 17 | 12 41 34 | − 4 16.9 | 9.5336 | 0.0921 | |
| 18 | 12 49 13 | − 5 32.2 | 9.5321 | 0.0987 | 10 25 |
| 19 | 12 56 53 | − 6 46.1 | 9.5336 | 0.1050 | |
| 20 | 13 04 34 | − 7 58.3 | 9.5374 | 0.1111 | 10 43 |
| 21 | 13 12 16 | − 9 8.9 | 9.5439 | 0.1169 | |
| 22 | 13 19 59 | − 10 17.7 | 9.5527 | 0.1225 | 11 00 |
| 23 | 13 27 41 | − 11 24.3 | 9.5634 | 0.1278 | |
| 24 | 13 35 21 | − 12 28.7 | 9.5757 | 0.1329 | 11 16 |
| 25 | 13 42 59 | − 13 30.5 | 9.5893 | 0.1378 | |
| 26 | 13 50 34 | − 14 29.9 | 9.6036 | 0.1426 | 11 31 |
| 27 | 13 58 06 | − 15 26.8 | 9.6187 | 0.1472 | |
| 28 | 14 05 33 | − 16 21.2 | 9.6341 | 0.1516 | 11 46 |
| 29 | 14 12 56 | − 17 13.1 | 9.6497 | 0.1560 | |
| 30 | 14 20 14 | − 18 2.4 | 9.6654 | 0.1604 | 12 00 |
| 31 | 14 27 27 | − 18 49.3 | 9.6809 | 0.1646 | |
| Nov. 1 | 14 34 36 | − 19 33.9 | 9.6963 | 0.1687 | 12 14 |

### *Ephemeris of Comet 1891 (Wolf's Periodic Comet).*

(Continued from page 367.)

| | App. R. A. h m s | App. Decl. ° ′ | log $r$ | log $\Delta$ | Br. |
|---|---|---|---|---|---|
| Oct. 5 | 4 31 23 | + 11 48.3 | 0.2110 | 9.9249 | |
| 6 | 32 20 | + 11 17.6 | | | |
| 7 | 33 15 | + 10 46.7 | 0.2121 | 9.9211 | |
| 8 | 34 07 | + 10 15.4 | | | |
| 9 | 34 55 | + 9 44.0 | 0.2133 | 9.9175 | |
| 10 | 35 41 | + 9 12.2 | | | |
| 11 | 36 25 | + 8 40.3 | 0.2145 | 9.9143 | |
| 12 | 37 05 | + 8 08.1 | | | |
| 13 | 37 43 | + 7 35.8 | 0.2158 | 9.9115 | 12.0 |
| 14 | 38 17 | + 7 03.3 | | | |
| 15 | 38 49 | + 6 30.8 | 0.2171 | 9.9089 | |
| 16 | 39 18 | + 5 58.1 | | | |
| 17 | 39 44 | + 5 25.3 | 0.2185 | 9.9068 | |
| 18 | 40 07 | + 4 52.5 | | | |
| 19 | 40 28 | + 4 19.6 | 0.2199 | 9.9050 | 12.1 |
| 20 | 40 46 | + 3 46.8 | | | |
| 21 | 41 01 | + 3 14.0 | 0.2214 | 9.9036 | |
| 22 | 41 13 | + 2 41.2 | | | |
| 23 | 41 22 | + 2 08.6 | 0.2230 | 9.9026 | |
| 24 | 41 29 | + 1 36.0 | | | |
| 25 | 41 33 | + 1 03.6 | 0.2246 | 9.9021 | 12.0 |
| 26 | 41 35 | + 0 31.3 | | | |
| 27 | 41 34 | − 0 00.8 | 0.2262 | 9.9020 | |

| Gr. M. T. | App. R. A. h m s | App. Decl. ° ′ | Log r | Log Δ | Light. |
|---|---|---|---|---|---|
| Oct. 28 | 4 41 30 | − 0 32.5 | | | |
| 29 | 41 24 | − 1 04.0 | 0.2279 | 9.9023 | |
| 30 | 41 16 | − 1 35.2 | | | |
| 31 | 41 05 | − 2 06.1 | 0.2296 | 9.9030 | |
| Nov. 1 | 40 52 | − 2 36.7 | | | |
| 2 | 40 37 | − 3 06.9 | 0.2313 | 9.9042 | |
| 3 | 40 20 | − 3 36.6 | | | |
| 4 | 40 01 | − 4 05.9 | 0.2331 | 9.9059 | |
| 5 | 39 40 | − 4 34.8 | | | |
| 6 | 39 17 | − 5 03.1 | 0.2350 | 9.9080 | 11.2 |
| 7 | 38 52 | − 5 31.0 | | | |
| 8 | 38 25 | − 5 58.2 | 0.2369 | 9.9105 | |
| 9 | 37 57 | − 6 25.0 | | | |
| 10 | 37 27 | − 6 51.1 | 0.2388 | 9.9135 | |
| 11 | 36 56 | − 7 16.6 | | | |
| 12 | 4 36 24 | − 7 41.6 | 0.2407 | 9.9169 | 10.4 |

*Total Eclipse of the Moon Nov. 15, 1891.* This will be visible generally throughout North and South America, Europe, Asia and Africa. In the eastern and central parts of the United States, the whole of the eclipse will be visible. In the western parts the moon will rise eclipsed. The following are the elements of the eclipse as given in the *American Ephemeris:*

Greenwich mean time of conjunction in right ascension, Nov. 15, $12^h$ $08^m$ $44.8^s$.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Sun's R. A. | $15^h$ | $23^m$ | $54.99^s$ | | Hourly motion | | $10.29^s$. | |
| Moon's R. A. | 3 | 23 | 54.99 | | Hourly motion | | 145.10 | |
| Sun's Decl. | 18° | 37′ | 41.1″ | S. | Hourly motion | 0′ | 37.9″ | S. |
| Moon's Decl. | 18 | 21 | 05.5 | N. | Hourly motion | 12 | 23.6 | N. |
| Sun's Equa. hor. parallax | | | 8.7 | | Sun's true semi-diam. | 16 | 10.9 | |
| Moon's Equa. " | | 60 | 03.2 | | Moon's true semi-diam. | 16 | 21.1 | |

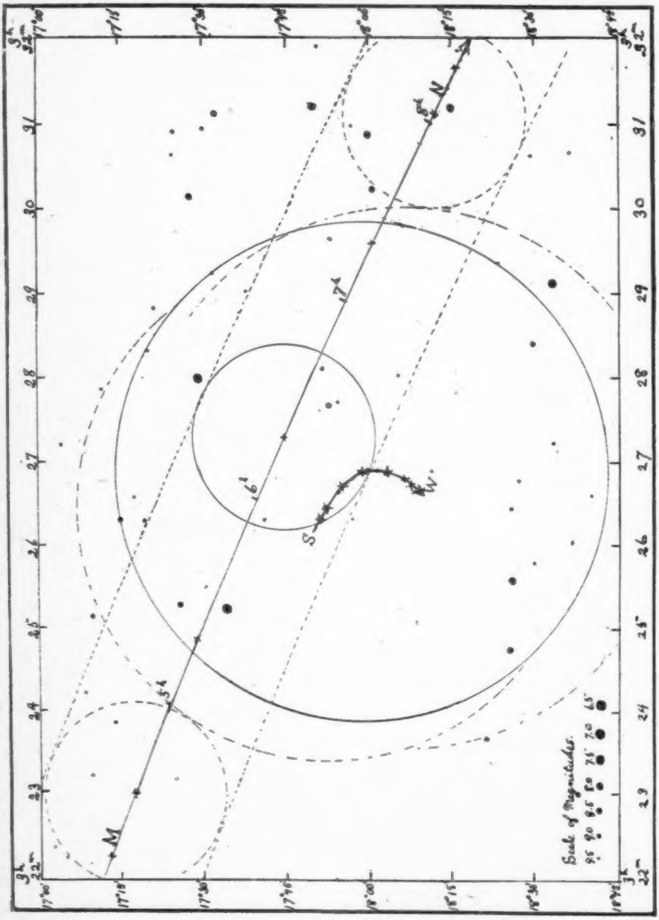
*Times of the Phases.*

| | Gr. Mean Time. | | Gr. Mean Time. |
|---|---|---|---|
| Moon enters penumbra | Nov. 15 9h 35.9m | Total eclipse ends | 13h 00.7m |
| Moon enters shadow | 10 35.0 | Moon leaves shadow | 14 03.0 |
| Total eclipse begins | 11 37.0 | Moon leaves penumbra | 15 02.6 |
| Middle of eclipse | 12 18.8 | | |

To obtain the standard times of these phases for any given place, subtract the longitude of the meridian which is employed as a standard for time at that place. Thus for a place using Eastern time, subtract $5^h$; for one using Central time substract $6^h$, etc., from the Greenwich times.

At Northfield the moon will be a little below the eastern horizon at $4^h$ $35^m$ central time, when it begins to enter the dark part of the earth's shadow.

During the eclipse the moon will occult a number of faint stars. Ordinarily the brightness of the moon's light effectually prevents us from seeing occultations of stars fainter than the seventh magnitude, but during a total eclipse the ruddy light is so mild that much fainter stars can be observed as they pass behind the moon's limb. All observations of the occultations of such stars are of value as data for determining the diameter of the moon and for deciding the question of the lunar atmosphere. The points to be noted are the exact times of disappearance and reappearance of the star, and any change in the physical appearance of the star as it approaches or recedes from the edge of the moon. The observer must determine accurately the error of his time-piece and the latitude and longitude of the place of observation.



In order to enable observers to see what stars will be occulted and to identify those which they may be able to observe, we have prepared a chart of the region of the sky in which the eclipse occurs. All stars down to the 9.5 magnitude are shown, the places being taken from Argelander's catalogue, known as the Durchmusterung. The apparent path of the moon and of the earth's shadow, as affected by parallax at Northfield, are also laid down on the chart. The line *MN* is the path of the moon's center. The small circles represent the moon at the beginning, middle and end of eclipse. The large circle represents a cross-section of the earth's shadow at the distance of the moon. The line *SW* is the apparent path of the center of

the cross-section of the shadow as seen from Northfield. The figures on the line *MN* are the hours of central time when the moon's center will be at the points marked. The figures on the margin of the cut give the right ascensions and declinations of the portions of sky represented.

It will be easy for observers in the vicinity of Northfield to determine approximately the time of immersion and emersion of each star, by simply drawing circles of the size given for the moon with their centers along the line *MN* and circumferences passing through the star in question, then measuring the proportional parts of hours along the line *MN*. For a place very distant from Northfield it will be necessary for the observer to calculate for his own station the path of the moon and plat it upon the chart.

For the convenience of observers, also Professor John A. Parkhurst has computed for a number of observatories in the United States, the times of immersion and emersion, and the angles from the north point and vertex of the moon where these will occur, for all of the stars likely to be occulted. We have added to the table which he has prepared, the corresponding data for Northfield, calculated by one of our own computers.

*List of Stars in and near the Earth's Shadow.*

| Star. | Mag. | R. A. 1892.0 | Decl. 1892.0. | Star. | Mag. | R. A. 1892.0 | Decl. 1892.0. |
|---|---|---|---|---|---|---|---|
| DM. + | | h. m. s. | ° ′ | DM. + | | h. m. s. | ° ′ |
| 17, 558 | 9.4 | 3 22 00 | + 18 06.5 | 17, 574 | 9.5 | 3 27 52 | + 17 11.5 |
| 16, 446 | 9.5 | 22 14 | 17 04.9 | 17, 575 | 7.0? | 28 00 | 17 29.3 |
| 16, 447 | 9.5 | 22 20 | 17 02.9 | 17, 576 | 9.5* | 28 02 | 18 05.7 |
| 17, 559 | 9.5 | 23 10 | 17 25.0 | 17, 577 | 9.5* | 28 07 | 17 51.5 |
| 17, 560 | 9.5 | 23 12 | 17 09.6 | 17, 578 | 9.0 | 28 20 | 17 20.5 |
| 18, 489 | 8.6 | 23 38 | 18 21.3 | 18, 505 | 9.3 | 28 24 | 18 29.9 |
| 17, 561 | 9.5 | 23 50 | 17 14.0 | 17, 579 | 9.3 | 28 49 | 17 21.1 |
| 17, 562 | 9.3 | 24 14 | 17 08.3 | 17, 580 | 9.5? | 29 02 | 17 37.5 |
| 18, 492 | 8.3 | 24 44 | 18 25.5 | 18, 507 | 7.0 | 29 07 | 18 33.4 |
| 18, 493 | 9.5 | 25 04 | 18 09.1 | 17, 581 | 9.5 | 29 14 | 17 31.6 |
| 17, 563 | 9.1 | 25 08 | 17 09.8 | 18, 508 | 9.5 | 29 21 | 18 23.8 |
| 17, 564 | 6.5* | 25 14 | 17 34.6 | 17, 582 | 9.3* | 29 39 | 17 52.8 |
| 17, 565 | 8.5* | 25 17 | 17 26.0 | 17, 583 | 9.5* | 29 48 | 18 06.4 |
| 17, 566 | 9.5 | 25 29 | 17 30.8 | 17, 584 | 8.3 | 30 09 | 17 27.8 |
| 18, 494 | 8.3 | 25 34 | 18 26.1 | 17, 585 | 8.5* | 30 13 | 18 00.7 |
| 18, 496 | 9.5 | 25 47 | 18 30.1 | 17, 586 | 9.5 | 30 37 | 17 24.6 |
| 18, 497 | 9.5 | 26 02 | 18 36.9 | 18, 511 | 9.5 | 30 38 | 18 29.6 |
| 17, 567 | 9.3? | 26 17 | 17 19.4 | 18, 512 | 9.4 | 30 41 | 18 36.3 |
| 17, 568 | 8.8 | 26 18 | 17 15.1 | 17, 587 | 8.0* | 30 52 | 18 00.0 |
| 17, 569 | 9.5* | 26 18 | 17 41.1 | 17, 588 | 9.3 | 30 55 | 17 24.7 |
| 17, 570 | 9.5? | 26 20 | 17 57.0 | 17, 589 | 9.3 | 30 57 | 17 30.4 |
| 18, 498 | 9.5 | 26 26 | 18 26.1 | 17, 590 | 9.5 | 30 58 | 17 56.7 |
| 17, 571 | 9.4 | 26 35 | 17 17.9 | 17, 591 | 8.5 | 31 07 | 17 32.7 |
| 18, 499 | 9.5 | 26 36 | 18 39.9 | 18, 514 | 8.3* | 31 11 | 18 15.2 |
| 18, 501 | 9.5 | 26 46 | 18 27.2 | 17, 592 | 8.5 | 31 13 | 17 49.9 |
| 18, 502 | 9.3 | 26 53 | 18 11.4 | 18, 516 | 9.5 | 31 52 | 18 16.3 |
| 17, 572 | 9.2* | 26 55 | 17 58.6 | 17, 593 | 9.0 | 31 54 | 18 06.1 |
| 16, 460 | 9.5 | 27 12 | 17 04.4 | 17, 594 | 9.5 | 31 55 | 17 50.8 |
| 18, 504 | 9.5 | 27 13 | 18 33.3 | 17, 595 | 8.2 | 32 19 | 17 15.0 |
| 17, 573 | 8.3* | 27 40 | 17 53.1 | | | | |

The places of the stars are taken from Argelander's Beobachtungen zu Bonn, Band III, and have been reduced to 1892.0.

The stars marked with an * will be occulted at Northfield. Those marked ? will perhaps be occulted at Northfield.

Those marked *, having greater R. A. than 3$^h$ 30$^m$ will be occulted after the moon passes partially out of the shadow.

### *Approximate Times of Occultations during the Lunar Eclipse, Nov. 15, 1891.*

Calculated by J. A. Parkhurst.

| STAR. | Albany. Eastern Time. Im. h m s | Albany. Eastern Time. Em. h m s | Rochester. Eastern Time. Im h m s | Rochester. Eastern Time. Em. h m s | Evanston. Central Time. Im. h m s | Evanston. Central Time. Em. h m s | Marengo. Central Time. Im. h m s | Marengo. Central Time. Em. h m s | Madison. Central Time. Im. h m s | Madison. Central Time. Em. h m s | Northfield. Central Time. Im. h m | Northfield. Central Time. Em. h m |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DM. + 17°, 559. | | | | | | | | | | | | |
| T | 5 9 36 | 6 0 54 | | | | | | 5 2 0 | | 5 4 35 | | |
| Angle from N | 57 | 254 | | | | | | 276 | | 265 | | |
| " " V | 105 | 303 | | | | | | 324 | | 313 | | |
| DM. + 17°, 561. | | | | | | | | | | | | |
| T | 5 23 0 | 5 58 54 | | | | | | 5 6 30 | | 5 7 4 | | |
| Angle from N | 112 | 198 | | | | | | 245 | | 215 | | |
| " " V | 160 | 248 | | | | | | 293 | | 262 | | |
| DM. + 17°, 562. | | | | | | | | | | | | |
| T | | | | | | | | | 4 47 5 | 4 54 26 | | |
| Angle from N | | | | | | | | | 146 | 167 | | |
| " " V | | | | | | | | | 196 | 217 | | |
| DM. + 17°, 564. | | | | | | | | | | | | |
| T | 5 57 52 | 6 52 9 | | 6 52 36 | 4 59 48 | 5 51 0 | 5 0 21 | 5 50 54 | 5 1 31 | 5 52 36 | 5 5.0 | 5 54.0 |
| Angle from N | 70 | 238 | | 243 | 72 | 250 | 60 | 251 | 60 | 253 | 56 | 256 |
| " " V | 118 | 288 | | 293 | 120 | 300 | 108 | 301 | 107 | 302 | | |
| DM. + 17°, 565. | | | | | | | | | | | | |
| T | 5 57 49 | 6 41 26 | | 6 43 27 | 5 2 11 | 5 43 53 | 4 57 45 | 5 44 23 | 4 59 5 | 5 46 44 | 5 1.3 | 5 49.0 |
| Angle from N | 100 | 208 | | 215 | 57 | 222 | 91 | 223 | 88 | 266 | 84 | 229 |
| " " V | 148 | 258 | | 265 | 105 | 272 | 138 | 272 | 134 | 314 | | |
| DM. + 17°, 566. | | | | | | | | | | | | |
| T | 6 2 36 | 6 52 51 | | 6 53 7 | 5 9 5 | 5 53 0 | 5 3 30 | 5 53 40 | 5 4 49 | 5 54 57 | 5 6.3 | 5 56.1 |
| Angle from N | 88 | 220 | | 226 | 84 | 233 | 78 | 234 | 76 | 236 | 74 | 238 |
| " " V | 138 | 271 | | 276 | 132 | 283 | 125 | 284 | 122 | 285 | | |
| DM. + 17°, 569. | | | | | | | | | | | | |
| T | 6 24 54 | 7 21 1 | 6 25 32 | 7 20 55 | 5 25 6 | 6 17 45 | 5 25 35 | 6 17 48 | 5 27 3 | 6 19 17 | 5 29.3 | 6 20.7 |
| Angle from N | 72 | 235 | 67 | 240 | 62 | 248 | 63 | 248 | 59 | 251 | 64 | 248 |
| " " V | 123 | 285 | 116 | 290 | 111 | 299 | 112 | 298 | 107 | 301 | | |
| DM. + 17°, 570. | | | | | | | | | | | | |
| T | 6 37 42 | 7 28 5 | 6 48 5 | 7 23 40 | 5 52 42 | 6 13 12 | 5 54 3 | 6 12 5 | | | | |
| Angle from N | 35 | 271 | 13 | 294 | 357 | 812 | 354 | 315 | | | | |
| " " V | 87 | 323 | 63 | 344 | 49 | 3 | 44 | 5 | | | | |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DM. + 17°, 572. | | | | | | | | | | | | |
| T | 6 57 48 | 7 45 6 | 7 0 47 | 7 41 39 | 6 3 13 | 6 31 35 | 6 3 55 | 6 30 47 | 6 7 1 | 6 30 34 | 6 15.8 | 6 25.2 |
| Angle from N | 26 | 279 | 19 | 286 | 6 | 302 | 4 | 304 | 1 | 308 | 346 | 325 |
| " " V | 76 | 330 | 69 | 336 | 56 | 353 | 54 | 355 | 50 | 358 | | |
| DM. + 17°, 573. | | | | | | | | | | | | |
| T | 7 3 18 | 8 2 51 | 7 3 30 | 8 2 40 | 6 1 46 | 6 55 44 | 6 2 22 | 6 55 2 | 6 3 23 | 6 56 24 | 6 8.8 | 6 56.8 |
| Angle from N | 65 | 239 | 60 | 249 | 53 | 255 | 67 | 257 | 49 | 258 | 41 | 268 |
| " " V | 116 | 289 | 110 | 299 | 103 | 306 | 118 | 308 | 98 | 308 | | |
| DM. + 17°, 576. | | | | | | | | | | | | |
| T | 7 25 30 | 8 19 6 | 7 26 45 | 8 15 45 | 6 27 39 | 7 4 46 | | | 6 30 45 | 7 4 14 | 6 13.2 | 7 7.2 |
| Angle from N | 33 | 270 | 27 | 256 | 52 | 292 | | | 10 | 297 | 59 | 249 |
| " " V | 84 | 319 | 77 | 306 | 103 | 342 | | | 60 | 347 | | |
| DM. + 17°, 577. | | | | | | | | | | | | |
| T | 7 13 24 | 8 10 36 | 7 12 45 | 8 9 55 | 6 9 31 | 7 5 7 | 6 9 37 | 7 5 26 | 6 10 57 | 7 6 13 | 6 37.4 | 7 4.0 |
| Angle from N | 81 | 224 | 75 | 229 | 61 | 240 | 67 | 241 | 66 | 243 | 3 | 304 |
| " " V | 131 | 274 | 125 | 279 | 112 | 291 | 117 | 292 | 105 | 293 | | |
| DM. + 17°, 582. | | | | | | | | | | | | |
| T | 8 3 19 | 8 34 0 | | | 6 45 1 | | 6 47 38 | 7 35 51 | 6 48 43 | 7 39 54 | 6 44.5 | 7 44.3 |
| Angle from N | 123 | 180 | | | 88 | | 97 | 276 | 95 | 210 | 88 | 219 |
| " " V | 173 | 229 | | | 139 | | 148 | 325 | 145 | 260 | | |
| DM. + 17°, 583. | | | | | | | | | | | | |
| T | 8 3 31 | 9 6 12 | 8 2 29 | | 6 56 57 | | 6 57 35 | | 6 58 17 | 7 56 49 | 6 52.2 | 7 48.6 |
| Angle from N | 74 | 228 | 66 | | 57 | | 56 | | 54 | 251 | 48 | 259 |
| " " V | 124 | 274 | 116 | | 108 | | 106 | | 104 | 301 | | |
| DM. + 17°, 585. | | | | | | | | | | | | |
| T | 8 16 24 | 9 2 42 | 7 59 42 | | 7 3 37 | | 7 4 35 | | 7 4 37 | | 7 10.7 | 8 4.6 |
| Angle from N | 105 | 287 | 91 | | 85 | | 84 | | 81 | | 51 | 256 |
| " " V | 155 | 333 | 141 | | 136 | | 135 | | 131 | | | |
| DM. + 18°, 511. | | | | | | | | | | | | |
| T | 8 52 18 | 9 43 24 | | | | | | | | | | |
| Angle from N | 21 | 282 | | | | | | | | | | |
| " " V | 67 | 322 | | | | | | | | | | |
| DM. + 17°, 587. | | | | | | | | | | | | |
| T | | | 8 38 9 | | 7 23 53 | | 7 23 30 | | 7 22 32 | | 7 30.1 | 8 17.1 |
| Angle from N | | | 358 | | 108 | | 103 | | 101 | | 101 | 204 |
| " " V | | | 46 | | 160 | | 152 | | 151 | | | |
| DM. + 17°, 590. | | | | | | | | | | | | |
| T | | | | | 7 31 18 | | | | 7 28 52 | | | |
| Angle from N | | | | | 126 | | | | 121 | | | |
| " " V | | | | | 178 | | | | 171 | | | |

## ASTRONOMY FOR AMATEURS.

### Drifting Meteor Trains.

E. E. BARNARD.

The observations of meteors and meteor trains by the naked eye is common, but the study of these interesting objects by the aid of the telescope, so far as we know, is almost wholly neglected, although such work might yield valuable results.

Whenever a train is visible to the unaided eye for several seconds of time, it can often be seen with the telescope for as many minutes; since this is so, such observations might throw light on the question regarding the existence of a constantly eastward current or currents in the upper atmosphere. We have kept a record of all the trains of meteors observed for nearly a year past, and give the following as the more important part of it:

In 1881, Nov. 16, near $7^h$ (full account given in *Science*, No. 75, Vol. 2, and *Science Observer* No. 35), magnificent meteor near Capella, many times brighter than *Venus*; traversed a path of about 10° in about two or three seconds toward the north-east; the train remaining plainly visible to the naked eye for six minutes, and in the telescope for over fifteen minutes, its width about one-fourth of a degree, its length the full extent of the meteor's path. The luminous train was knotted with cloudy tufts and crooked in a most curious manner, constantly changing, and of a bright pinkish color. It moved north-east four degrees in fifteen minutes of time.

August 5, near $9^h$, 1882; Brighter than a first magnitude star, of a whitish color, rapid in motion, passing a little east of over head. Its flight was from *Cassiopeia* to *Scorpio*. This meteor left a streak nearly 60° long, visible to the naked eye for a few seconds only, but watched in the telescope for fully ten minutes, where it appeared first, very bright and unbroken, straight as a shaft, clean and sharp in outline, and brighter along the axis, but in two seconds it became crooked and sinuous, drifting south-east at the rate of about one degree in two minutes (at this time there was a faint breeze *from* the south-east). The brightness of the train remained very prominent, though it became more and more distorted and crooked each moment. Near the point of disappearance of the meteor there was a very bright irregular mass of glowing vapor which retained its brightness longest, and had the irregularity of the great nebula of *Orion*, which it somewhat resembled at times. The gaseous train was more or less distinct, though getting faint when observation ceased. The color of this train was that of lightish smoke tinged with a warm glow especially in the southern part of the train near *Scorpio*. A few seconds after the appearance of this meteor, a similar one shot rapidly across the heavens from *Cassiopeia* to the east of south; a train from it was visible for several seconds, but there was no time to examine it with the telescope.

August 10, near $10^h$, two bright meteors, white in color, of the first magnitude were seen within a few minutes; both had short paths and came from *Cassiopeia*; very quick in flight, following nearly the same path toward the west. The track of each meteor was examined—almost while

the meteors were in flight—that part of the sky being watched in the hope of catching a meteor in motion. The trains were seen and were similar in every respect, a narrow streak 3° or 4° long melting away in about two or three seconds, affording merely a glimpse: both were straight, their duration was too short to detect any motion; color, light warm.

August 11, near $15^h$, nearly of first magnitude, whitish, appeared just north of $\beta$ of *Auriga*, and traversed a path of about 20° very quickly toward the south: luminous train full length of path, visible to the eye only for a second or two, but watched in the telescope for nearly five seconds in which it appeared long and perfectly straight, much brighter along the axis, but in a few seconds it began to crook and bend, moving rapidly south-east. A bright knot became visible in it which moved much more rapidly, seeming to pull the rest of the luminous streak after it. The motion toward the south east was one degree in one minute and ten seconds, the train, a pale warm color.

August 18, near $10^h 30^m$. Fine meteor equal to a first magnitude star. Very rapid flight towards the south-west, passing a little east of $\alpha$ of *Capricornus*. Luminous train seen with the naked eye only a few seconds, but visible in the telescope for fully ten minutes; at first, as a thin straight line which in a few seconds began to bend and crook itself into serpentine curves, moving the meanwhile slowly toward the north-east, about one degree in three and a quarter minutes. In places along the train were brighter cloudy masses. These had a motion greater than the general train.

August 19, near $13^h 30^m$, a fine bright meteor of the first magnitude, of a whitish color, shot very rapidly across *Cetus* just south-east of *Mira*; motion towards the south, slightly west. Duration of flight over one and one-half seconds, train visible to the eye for about two seconds; with the telescope the train was not continuous, there being little or none of the luminous smoke where the meteor disappeared, while near the point of appearance lay a very bright strip some 30′ long and about 1′ broad; between this and the south end of the train were numerous bright cloudy masses. The train became quickly distorted, one bright portion moved more rapidly, the rest following in its wake. The bright mass was visible for nearly three minutes, moving at the rate of one degree in thirty-two seconds. This gradually faded from sight without diffusion seeming to melt from view. During the watch it had expanded slightly in size. This train had the most rapid motion of any before observed. The brightest parts would be but a little less than the nebula of *Orion*.

From the above observations many interesting thoughts are suggested. It is apparent that the opportunity for continued observation of the luminous smoke left by the meteor in its retarded flight through our atmosphere, is not so very rare and its existence not so transient as might be supposed, not infrequently offering ten or fifteen minutes of observation and possibly, in some rare instances, remaining visible in good telescopes for several hours, thus affording sufficient time for examination into their chemical composition by the aid of the spectroscope. The idea suggests itself to us that observations of the motions of these trains would be invaluable in determining atmospheric currents at great altitudes, there

being now no possible means of knowing anything relative to the existence and direction of currents in the upper strata of our atmosphere.

We can ascend but a few miles at most in balloons, and the highest clouds reach very little above that, and at such low altitudes the atmospheric currents are likely to be disturbed and greatly changed by local causes, such as mountain chains, etc. But at such great altitudes where the meteor first enters our atmosphere, there are no local causes to disturb the general direction of the currents, and if we were only able to observe their motion a much better knowledge of the physical construction of our globe's envelope of air might be had.

It is utterly impossible to detect, by artificial means, the motion of air currents at great distances above the earth. Were it possible to place any object in the upper part of the atmosphere to drift with the currents then we could determine by observation of its movements the direction of motion, velocity etc., of the currents; or were it possible for clouds to form in the rarer strata, we could by observing them determine the currents along which they drift. As these are manifestly impossibilities we can have recourse to but one agency for bettering our knowledge of the upper currents, and that is, to take advantage of the opportunity afforded by the luminous train left by the occasional meteor.

The meteor strikes our atmosphere with a great velocity—forty or fifty miles a second. Passing our hand through the air we feel but little or no resistance, and certainly no sensible increase of heat, but when that motion is increased a hundred thousand fold, as in the case of the meteor, the resistance encountered is great so that the moving body is at once converted into an incandescent mass of light. Thus the meteor, hurrying swiftly through space, suddenly rushes into our atmosphere which acts like an almost impenetrable shield, checking its velocity which is quickly converted into intense heat, many times greater than that of the hottest furnace. As the meteor is being consumed, it leaves a train of luminous gas or smoke which can but float along with the current of air in the same manner that the smoke from our chimneys moves through the atmosphere and, like it, indicating the direction of the wind or air currents. By frequent observations of these drifting gas trains a general idea could be formed as to the existence and direction of those upper currents. So far, my observations indicate the existence of an easterly current, or currents, of possibly long duration. All the trains observed were drifting easterly, either directly east, or north, or south-east; some in a direction opposite to the meteors' flight. If there were no currents where the meteor passed, we would naturally expect the train from inertia to move slowly in the direction the meteor went; but it is seen that the train overcomes that and assumes a motion that depends undoubtedly on that of a regular current in our atmosphere.

The peculiarity of bending and twisting in meteor trains is produced by denser portions of the gaseous matter. It may be suggested that these are heavier particles sinking more rapidly earth-ward, though these particles will doubtless sink thus towards the earth, yet they are seen, sometimes, to move in a direction different to that we would expect if such were the case. They seem to be more at the will of the air currents, along which the train drifts and are followed by the less dense portions of smoke. These are possibly small fragments thrown off from the meteor by minor explosions. Another remarkable thing is the quantity of luminous gas constituting these trains; in nearly every case it has exceeded three or four cubic miles. This is a great quanity of gas to be evolved by the combustion of such an insignificant thing as the meteor is. It is singular that the train should remain luminous so long. It must be burning to be seen; but why burn so long, as fifteen minutes?

This kind of observation is particularly suited to amateurs. The regular observer with a dome over his head can not do much of this kind of work. But any one with a telescope properly mounted, with a knowledge of the diameter of the field of his eye-piece, and with a desire to do something, can do valuable work by keeping a sharp lookout for bright meteors, quickly examining their paths and recording what he sees. This work is especially adapted to comet sweepers, as they are generally in the open air, and have instruments capable of quick change of position.

To those beginning such observations it may be well to say: Note the direction of flight of the meteor; turn the telescope at once to its path, sweep rapidly back and forth over the place where the meteor passed. If there is a train left you will likely strike it the first sweep. If bright and persistent, sweep the full length of it examining any peculiarities; then let your telescope stand at rest and allow the train to pass across the field, note the time it requires to pass through from edge to edge of field, taking into account the motion of the sky, note the direction of motion, the width of the train, the time of observation within a few minutes, note the point of observation in the sky, etc. When the train begins to bend or become irregular, which it is sure to do if it remains visible any length of time, see if the forward positions (in the direction of motion) are brighter than the general train. It would be well to watch the stars it passes over, also to note if there is any change in steadiness and brightness as the luminous mass passes over them; write out your observations and send them to the SIDEREAL MESSENGER or some other scientific journal where they will receive proper attention. If several observers some distance apart could attend to this kind of work and carefully record the paths of the meteors seen, it is likely that the same object might be examined by two or more and its height above the earth could be determined, and therefore the actual velocity with which its train moves and the quantity of gaseous matter it contains. [*Reprint from Vol. I by request.*—ED.]

NASHVILLE, Tenn., Sept. 20, 1882.

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## Astronomical Society of the Pacific.

CHARLES BURCKHALTER, SECRETARY.

Meeting of the Astronomical Society of the Pacific held at Lick Observatory Sept. 5th.

The Directors Meeting was held from 5:30 to 6 o'clock, President Pierson presiding. The minutes of last meeting were approved, and twenty five members were elected as follows:

Robert Stanton Avery, 302 A Street, Washington, D. C.; R. L. Bischoffsheim, 3 Rue Taitbout, Paris, France; Dr. Charles M. Blake, 1840 Howard Street, S. F., Cal.; Mrs. E. E. Cook, 220 Main Street, Davenport, Iowa; Alfred L. Edwards, 12 W. 33d Street, New York City; T. A. Hagerty, 537 Belden Ave., Chicago, Ill.; John P. Hely, C. E., 418 Claremont Ave, Chicago Ill.; Kirk Himrod, 150 Lincoln Ave., Chicago, Ill.; Williams Hoskins, Lagrange, Cook Co., Ill.; Mrs. M. M Johnson, Circleville, Piute Co., Utah; Professor J. H. Kedzie, Evanston, Ill.; Professor Malcolm McNeill, Lake Forest, Ill.; Beverly K. Moore, 56 Bedford Street, Boston, Mass.; Miss Pendleton, 1522 Locust Street, Philadelphia, Pa.; Mrs. William Gibbons Preston, The Berkeley, Boston, Mass.; Miss M. J. Turner, 11 Faxon Ave., Quincy, Mass.; Professor J. M. Taylor, State University, Seattle, Wash.; J. M. Van Slyke, 29 S. Pinckney St., Madison, Wis.; David Hewes, Miss Anna Lathrop Hewes, and Frank McMullen, San Francisco; Frederick H. Whitworth and Professor J. M. Taylor, Seattle ,Washington; Miss Mary E. Wilson, Oakland, California; J. Henry Turner, Woodville, Virginia. The membership of the Society is now 420, of whom forty four are life members.

The meeting of the Society was held in the Library of the Observatory, President Pierson in the chair. The minutes of last meeting were approved.

The Secretary read a list of thirty-eight presents received since last meeting and the thanks of the Society were voted to the donors.

The following papers were presented:

*a.* Measurement of Jupiter's Satellites by interference methods, by Professor Michelson, of Clark University, Massachusetts.

*b.* Enlarged Drawings from the Moon-Negatives of the Lick Observatory, by Professor Weinek, Director of the Observatory of Prague.

*c.* Catalogue of the Library of the Society, prepared by Otto Von Geldern.

*d.* Observations of Jupiter and of his Satellites with the 36-inch Equatorial of the Lick Observatory [1888-1890].

*e.* The Observatory of the United States Military Academy at West Point, by Lieut. Harlow, in charge.

Only a was read by Professor Campbell and the meeting adjourned.

After adjournment the members were admitted to the domes of the twelve and thirty-six-inch telescopes and made the most of the superb seeing until a late hour.

## NEWS AND NOTES.

Foreign subscribers will please draw post orders or notes on St. Paul instead of Northfield, in payment of subscriptions to the MESSENGER, as the latter place has no foreign money order post office.

*The Chicago Evening Journal*, September 8, reports an interview with Professor Hough, Director of the Observatory of the Northwestern University at Evanston, concerning the 40-inch lens which is now being made by Alvan Clark, Cambridge, Mass., for the Observatory to be located on Wilson's Peak, California. In this interview Professor Hough is reported as saying "that the great objective will cost $60,000, that the telescope, including objective, mounting and machinery, will probably cost $120,000. The Observatory and dome will cost, as near as can be judged, about $30,000.

From this report it appears that plans are being made to have this great telescope completed in time to exhibit it at the Columbian Exposition in Chicago in 1893.

*New Spectroscope for Allegheny Observatory.* From a letter under date of Sept. 21, we learn that Professor J. E. Keeler has been provided with funds to secure a new spectroscope of the most efficient kind, to carry on his special studies. Mrs. Wm. Thaw, of Pittsburgh, is the generous donor of the money and J. A. Brashear, of Allegheny City, will make the spectroscope.

*Wm. F. Rigge, S. J.*, has been appointed successor to C. M. Charroppin in the department of Mathematics and Astronomy in the St. Louis University. Professor Rigge will soon have a 3¼-inch equatorial telescope and undertake astronomical work in the Observatory of the University.

*The Photochronograph.* We have been greatly interested in a paper recently sent us by J. G. Hagen, S. J., Director of Georgetown College Observatory, entitled *The Photochronograph and its Applications.* A considerable part of the work for this paper was done some time ago. We had not seen the account of the experiments that was published in the Woodstock College Print, Woodstock, Md. Vol. 18, No. 3, p. 402, for October, 1889. By these experiments important advancement seems to be made in photographing the transit of a star. Professor Hagen has prepared a valuable paper.

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*The Distribution of the Moon's Heat and its Variation with the Phase* is the title of a prize essay prepared by Frank W. Very, of the Allegheny Observatory. The essay was presented to the Utrecht Society of Arts and Sciences, in response to the proposition

"On demande de déterminer la chaleur donnée par la Lune dans des phases diverses."

It obtained the prize of the General Assembly of the Society held at Utrecht on the 2d of July, 1890.

A full abstract of this paper, with illustrations, will be published in a future number of THE MESSENGER, for it is certainly an essay of very high merit.

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*Transit of Jupiter's III Satellite.* I beg leave to report the following observations of the transit of Jupiter's third satellite and its shadow last evening:

At $7^h 30^m$, when the observations began, the satellite was near the central line of the planet and the shadow near the eastern limb. The shadow appeared jet black, round and larger by about one third than III, which appeared at the time round and of a dark chocolate or reddish brown hue. Both shadow and satellite were very distinct and sharply defined on the disc of the planet and the "seeing" was remarkably good and steady.

After the satellite passed the central line of the planet it appeared to grow smaller and its outlines became very irregular and, when about half way between the central line and western limb of the planet, it was very small and, in shape, nearly a half moon, but very irregular in outline. This appearance continued until the satellite reached a point on the disc about 3 or 4 diameters of the satellite from the western limb, or about where the belts begin to shade down (so to speak), when it gradually became a brilliant white, well-defined, much larger than the former dusky appearance and *perfectly round.* It so remained plainly visible on the planet during the rest of the transit and came off the limb white and brilliant against the dark sky. At egress, the limb of the planet, at the point of contact, appeared to flatten down, and shrink away from the satellite (an optical illusion, of course) the limb being sharply defined and the whole planet exquisitely distinct.

The instrument used was a 5 in. refractor (just received from Messrs. Alvan Clark & Sons) with powers of 105 and 200. E. S. MARTIN.

Wilmington, N. C., Sept. 18, 1891.

*August Meteors.* There was a remarkably fine display of August Meteors here last night. The air was clear and still and, notwithstanding the moonlight, the meteors flashed forth in great numbers and brilliancy. From $8^h\ 30^m$ P. M. to $11^h\ 30^m$ P. M. (when I retired) there was an almost constant discharge of meteors, all apparently radiating from the same point or region, the Constellation Perseus, and the numbers increased as that Constellation rose higher.

The meteors were mostly small—lasting only a moment—though some of them were very fine and left behind them a stream of light, or vapor, like the tail of a comet, which lasted, in some instances, a considerable time after the meteor had disappeared.

I observed a remarkably brilliant and handsome meteor at $9^h\ 30^m$ which travelled slowly, from a point between N. and N. E., across the meridian between Polaris and Vega, down towards the S. W., vanishing about the Constellation Libra. It appeared larger and brighter than Jupiter now appears to the naked eye, and had a haze or coma around it like the nucleus of a comet and left behind it a stream of light, or vapor, some 30° in length, which slowly faded away.

The number of meteors may be safely put at an average of at least five per minute for the three hours that I observed, though at times, more than that number were visible at once flashing across the sky in the different directions, but all radiating from one source. They seemed to come in groups or shoals and not in a a continuous stream.

It is the finest meteoric display I have observed since that of the November meteors in 1867. E. S. MARTIN.

Wilmington, N. C., August 11, 1891.

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*Spectroscopic Astronomy.* Dr. William Huggins has kindly favored THE MESSENGER with a copy of his address, as President, recently given before the British Association for the Advancement of Science. The address presents a full and very complete outline of the history of the spectroscope in Astronomy, and American astronomers will read it with great interest. It is published by the Association and the London daily papers.

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*An Astronomer's Work in a Modern Observatory* is the title of a paper by David Gill, Astronomer at the Cape of Good Hope, read before the meeting of the Royal Institution of Great Britain, May 29, 1891. The author says that the work of Astronomical Observatories has been divided into two classes, viz.: Astrometry and Astrophysics. The first of these relates to astronomy of precision, that is, to the determination of the position of celestial objects; the second relates to the study of their physical features and chemical constitution. Some years ago these two classes were considered as perfectly distinct; but latterly they have become so interlaced that they cannot be divided advantageously, and a fully equipped modern Observatory will include the work of *Astrometry* and *Astrophysics.*

The discussion of this theme is a very profitable one, extending through fifteen printed pages of the size of this one. One full-page plate, a fine engraving, shows the spectrum of Sirius as compared with iron; that of $\alpha$ Aurigæ and that of $\beta$ Aurigæ.

XUM